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HAWAII AGRICULTURAL EXPERIMENT STATION,

E. V. WILCOX, Special Agent in Charge.

ANNUAL REPORT

OF THE

HAWAII AGRICULTURAL EXPERIMENT STATION

FOR

1911.

UNDER THE SUPERVISION OF

OFFICE OF EXPERIMENT STATIONS,

U. S. DEPARTMENT OF AGRICULTURE.

WASHINGTON:
1912.

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HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU.

[Under the supervision of A. C. TRUE, Director of the Office of Experiment Stations, United States Department of Agriculture.]

WALTER H. EVANS, *Chief of Division of Insular Stations, Office of Experiment Stations.*

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LETTER OF TRANSMITTAL.

HAWAII AGRICULTURAL EXPERIMENT STATION,
Honolulu, Hawaii, October 2, 1911.

SIR: I have the honor to transmit herewith and to recommend for publication the Annual Report of the Hawaii Agricultural Experiment Station for the fiscal year ended June 30, 1911.

Respectfully,

E. V. WILCOX,
Special Agent in Charge.

Dr. A. C. TRUE,
Director Office of Experiment Stations,
U. S. Department of Agriculture, Washington, D. C.

Publication recommended.
A. C. TRUE, *Director.*

Publication authorized.
JAMES WILSON,
Secretary of Agriculture.

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ANNUAL REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION FOR 1911

SUMMARY OF INVESTIGATIONS.

By E. V. Wilcox, *Special Agent in Charge.*

BUILDINGS AND GROUNDS.

The new office building erected the previous fiscal year has served well the purpose for which it was erected, and is now used exclusively for the library, general office, and office of the entomologist. The quarters of the agronomist are in one portion of the old office building, which has been completely remodeled to accommodate the work of the departments of chemistry and agronomy. During the fiscal year ended June 30, 1911, a ginhouse was built for the better handling of the experimental cotton crops. In the center of the building the roller gin and gasoline engine are placed on cement bases, while around the sides of the building are arranged bins for holding seed and lint and for curing the seed cotton before ginning. Among the needs of the station for new buildings there is none greater than that of a glass propagating house in which the various seedlings can be properly protected from rain, wind, insects, and birds, and in which temperature conditions can be controlled, particularly to furnish bottom heat for certain seeds which require such heat in order to germinate properly. It is hoped that sufficient money may be obtained from Territorial funds during the next fiscal year to construct such a propagation house.

When the ground upon which most of the buildings of this station stand was formally turned over to the Department of Agriculture by the Navy Department a 2-acre plat located on Magazine Hill, near the front wall of Punchbowl, was also included. This ground has been cleared and planted to corn, cotton, and broom corn. The plat is in a very dry locality, most of the trade wind rains failing to reach it. Moreover, the soil is rather sandy and porous. An experiment has been carried on this year to determine how successfully corn, broom corn, and cotton will grow under such dry conditions. The best success was obtained with corn, particularly with the Yellow Creole variety.

On the slopes of Tantalus, at an elevation of about 750 feet, another small area which has previously not been cultivated was cleared and planted in Caravonica cotton, in order to compare the growth of this variety at the higher and the lower altitudes.

CHANGES IN STATION STAFF.

During the year a few changes occurred in the staff of the station. Mr. F. G. Krauss resigned and his place was filled by the appointment of Mr. C. K. McClelland. Miss Alice R. Thompson being on a furlough for a year, it became necessary to appoint another assistant chemist. This position has been filled by the appointment of Mr. W. T. McGeorge. Mr. W. P. Kelley, the chemist, has planned for a furlough during the coming fiscal year, and therefore the chemical department will have but two members of the force during the year.

DEMONSTRATION FARMS.

At the recent session of the Territorial legislature an appropriation of $20,000 was made for this station for the biennial period. It is understood that this sum of $10,000 per year is to be used chiefly in the establishment and maintenance of demonstration farms. Three such farms have already been located and are in operation. On the windward side of Hawaii two demonstration farms have been located, one at Hilo and one at Glenwood. At Hilo the area at the disposal of the station is about 2 acres, while the farm at Glenwood occupies 15 acres. The small plat at Hilo is taken up at present with experiments on bananas and taro. The renewed interest which has been shown in bananas has made it desirable to get some reliable data on the proper planting distance for Bluefields bananas and on fertilizers and cultural methods for this crop under the climatic conditions at Hilo. There was formerly a somewhat extensive banana industry in Hilo, and it is hoped that this may be revived with proper encouragement.

The problems to be studied at Glenwood are peculiar to that locality, but any results which may be obtained by careful experiments there will apply to a large area of possible homestead land. Many attempts have been made in the past to raise various crops such as are used in diversified agriculture and also sugar cane on the peculiar soils of this region, but without satisfactory results. The rainfall is very high, the soils being saturated most of the time. Moreover, the underlying strata of the soil are apparently of entirely different nature from the upper 3 or 4 inches, and while easily tilled and apparently porous are nevertheless difficult of aeration. The usual experience of attempting to raise crops on this soil has been that while the first crop was satisfactory in quantity a decided falling

off in the yield occurred in the second year and was more pronounced in any subsequent attempts at cultivation. It is necessary to determine what can be done in aerating this soil by different systems of plowing, including blasting with dynamite, fallowing, and burning the surface by means of log fires. Such burning of the soil in a few other localities in the Territory has given striking results in improving the physical structure of the soil and increasing the yields obtained. There is an encouraging local interest in solving these problems, and to this end $1,000 per year for a period of at least five years has been subscribed by private individuals and companies to supplement the Territorial funds in carrying on the experiments.

COOPERATIVE EXPERIMENTS.

During the year a number of cooperative experiments have been carried on by arrangements with private individuals and companies. These experiments have included attempts to determine whether pineapples may be improved in form by selection of suckers from plants which bear fruit of the most desirable form; also fertilizer experiments with taro and rice, methods of propagating and the cultural requirements of the yellow sweet potato of the mainland, and pruning experiments with cotton. It is still too early to feel sure of the results from the selection work with pineapples. In the cooperative fertilizer experiment with taro it is obvious that this plant, like rice, is benefited by allowing the soil to dry out and become aerated between crops, by applying all of the fertilizer before planting rather than after planting or in fractional doses, and by using sulphate of ammonia rather than nitrate of soda as a source of nitrogen. It has been found that the yellow sweet potato, known under various names on the mainland, may be made to yield a good quality of tubers in various localities in the Territory and that these tubers bring a high price (up to 8 cents per pound) when shipped to California during the season when mainland sweet potatoes are not to be had. The pruning experiments with cotton are only well under way. They are designed to test out on a large scale the results which have already been obtained on smaller areas upon the station grounds.

ENTOMOLOGICAL INVESTIGATIONS.

During the year the most important entomological occurrence in Hawaii was the discovery of the Mediterranean fruit fly. It is not certain when this pest first found its way into Hawaii, but, at any rate, the presence of the insect was not definitely known until this year. After its discovery it spread with remarkable rapidity, attacking peaches, all of the citrus fruits, mangoes, peppers, guavas, figs, and

avocados. The occurrence of this pest in Hawaii led to the prompt establishment of a quarantine on the part of California against Hawaiian fruits, except pineapples and bananas. The last two fruits are the only ones which were already being shipped in large quantities to the mainland, but there is an increasing demand in California and elsewhere for avocados, mangoes, and also papayas. The outlet for these fruits is therefore completely closed for the present until some effective method of control can be devised. This station has taken part in devising such a plan. The essential features of the plan at present consist in the careful daily collection of all fallen fruit and the removal of such fruit by the official garbage collectors, followed by burning, or collection by hog raisers, who boil the fruit before feeding. The results of this campaign are already evident and it seems possible gradually to reduce the numbers of the fly by this same means if the proper cooperation of householders and all interested parties can be maintained.

The growing importance of corn and leguminous crops in the problem of securing more forage has led to the cultivation of greatly increased areas of these crops and has also directed attention to some of their insect pests. The entomologist gave particular attention during the year to the insect pests of legumes and corn. The most important pests of legumes are considered in this report, and those of corn are to be treated in a forthcoming bulletin of the station. In these investigations it has been found that in some localities plant lice are very effectively parasitized. By artificially distributing these parasites about 95 per cent of the plant lice were attacked and destroyed. It is hoped that these parasites will become of great value in checking the annual losses from plant lice. Some attention has been given to the possible control of the cotton bollworm by means of parasites. A parasite is already known in Hawaii which destroys from 5 to 10 per cent of the bollworms, but a more effective one must be secured if possible. The Cotton Growers' Association, recently organized, proposes to raise sufficient funds to obtain additional parasites from India and other places where this pest is native.

HORTICULTURAL INVESTIGATIONS.

One of the chief lines of study during the year was concerned with the avocado. A budding method has been perfected by means of which success is obtained on young trees in from 85 to 90 per cent of cases and on old trees, by the method of top-working, in from 50 to 75 per cent of cases. Moreover, a successful inarching method has been devised for rapidly testing out promising seedlings. A collection has been made, as complete as possible, of the types of avocados found in Hawaii and a system of classification and description is now

being worked out. This fruit shows a great variety of forms, not only of shape, color, and flavor, but also in the relative proportion of pulp to seed and in the thickness of the rind.

The variation in the flavor, size, and shape of papaya fruits is almost unlimited. A part of this variation seems to be due to the crossings which have taken place between the different varieties or perhaps between species. The only practical method of propagating papayas is by means of seed. Obviously, therefore, in order to eliminate variation and establish varieties which will come true it is necessary in some manner to prevent too much crossing. In the work done on papayas at this station it has been found possible to propagate the fruit by the use of monœcious trees without the help of sterile male trees. If it should prove a practical matter to secure the desired flavor and other qualities by this method alone, it will thereby become possible to avoid the loss of space incident to the growing of a large number of male trees and the lack of uniformity which has hitherto occurred when dependence was placed on the fertilization of the pistils of one form of diœcious trees with the pollen of another form.

During the year the station has had an unusual number of requests for budwood of various fruit trees and for seedlings of these and various ornamentals. The requests of this sort from the War and Navy Departments have been the largest, and so far as possible the station has cooperated in furnishing material to improve the grounds of the newly established Army posts and naval stations. The larger part of the distribution of such material made by the station is directly along the lines of work now being carried on. An attempt is being made to reduce so far as possible the distribution of miscellaneous sorts in order that this may not interfere with the time of the members of the staff. Attention has previously been called to the fact that some of this work of distributing ornamentals and miscellaneous fruits and vegetables should be taken up on a commercial scale by some nurseryman.

CHEMICAL INVESTIGATIONS.

The investigation of manganese soils has been continued during the year. The results obtained in this work have added greatly to the knowledge of conditions which prevail in these soils and have helped to shape a practical policy of utilizing these soils, particularly in the pineapple districts. It may now be confidently asserted that highly manganiferous soils should be avoided in planting pineapples. This fruit is exceptionally sensitive to unfavorable soil conditions and can not be made to thrive on soils which contain from 4 to 5 per cent of manganese. A number of other crops are less sensitive to manganese and thrive fairly well on such soils. Among these may be mentioned

sugar cane, corn, and cotton. If for any reason it is especially desired to grow pineapples on highly manganiferous soils, the best results can be obtained by planting the old stumps rather than the suckers and by fertilizing heavily with phosphates.

It appears more and more certain that pineapples do not require so much water as has sometimes been supposed; in fact, one of the most serious difficulties in the pineapple district of Wahiawa, where about 5,000 acres of pineapples are grown, is in securing the proper drainage of the soils. It has been necessary to plow the land in such a way as to obtain ditches with the proper grade to carry off the excess of water. Tiles for drainage are too expensive in Hawaii and they can not be thought of as a practical treatment of the drainage problem at present. It is of great importance that the cultivation of pineapple soils should be avoided when these soils are too wet, otherwise they will become so badly puddled as to make proper drainage impossible. There are locations, particularly on Maui and Kauai, where the soils are not so easily puddled and where drainage is naturally accomplished in a satisfactory way, even in the presence of a larger rainfall than occurs in the Wahiawa section. On properly tilled soils the experiments thus far carried on with fertilizers show that the best combination for pineapples is superphosphate, sulphate of potash, and ammonium sulphate.

The fertilizer experiments with rice have been continued on the same plats and along the same line as was reported last year. The results secured on the two crops during the year were strictly in harmony with those previously obtained. It is evident that all the fertilizer should be applied to rice before planting and that nitrogen should be supplied in the organic form or in the form of ammonia rather than as nitrate.

In the fertilizer experiments with cotton a large increase in yield was brought about by a proper combination of different elements of plant food. The results as a whole, however, show that on the soils thus far used for growing cotton, phosphoric acid is the element which is most needed and the one which produces the most striking increase in yield.

Data are gradually being accumulated for a general classification of Hawaiian soils. It is impossible to classify them according to the schemes ordinarily adopted on the mainland, for the reason that physical and chemical properties of Hawaiian soils are so peculiar that the soils do not readily fall into mainland categories of classification. Among some of the more strikingly peculiar soils it is only necessary to mention those which contain from 8 to 10 per cent of manganese and an area which was recently found to contain 20 per cent of titanium.

The work in prospect for the coming year includes a study of sisal waste, the determination of the amount of oil in the kukui nut and practical methods for extracting it, a study of pineapple stumps with reference to their possible use in starch manufacture, a study of the prevalence of chlorin and sulphur in plants, and tests of the effect of heat on soils which show poor drainage.

COTTON.

Interest in cotton in Hawaii continues to increase, and the results thus far obtained justify the much larger plantings which have already been made. It was necessary in the first place to carry on much experimental work to determine under what conditions cotton would thrive best and the cultural methods which must be adopted to insure success. All cotton plantings in the Territory at low elevations or in localities protected against the trade wind have shown large yields of lint of good quality. The returns coming in from the early crop show yields of from 400 to 600 pounds of lint per acre, and also indicate that a practical method of holding the bollworm injury within bounds is now in operation.

One of the unsuspected results obtained in the cotton experiments of the station is the proof of the peculiar sensitiveness of cotton to even moderately cool weather. At low altitudes the temperature rarely falls as low as 60° F. At such a temperature, however, if accompanied by moderate trade winds, the leaves of cotton may be browned and curled as if frostbitten. While the trade winds are never strong as compared with the high winds which occasionally prevail on the mainland, yet their constant blowing from one direction largely prevents the setting of the bolls on the outside row of cotton toward the northeast. In isolated plants the windward side may be without bolls while the leeward side of the same plant is heavily loaded. The beneficial effect of windbreaks is very pronounced in all cotton fields exposed directly to the trade winds. In protected localities, however, the growth, yield, and quality are all that can be desired.

A number of plantings have been made in coral sand at sea level, even on the windward side of the islands, and in all of these plantings the cotton has grown and borne well. It appears that no injury is produced even if the roots reach down into the salt water. Heavily bearing plants may be seen in sand not over 2 feet above sea level and within 10 feet of the water's edge. In Hawaii, as elsewhere, it is evident that cotton can not obtain too much sun nor too much heat, but that too much rain may be injurious.

Success with cotton in Hawaii is not determined by altitude alone, for excellent fields are to be seen at altitudes of from 700 to 1,600 feet. These, however, are located in sections where the trade wind is broken by mountains. It is impossible to give with certainty the

rainfall which cotton will endure, but in soils retentive of moisture a good crop has been made with 15 inches of rain, and the other limit of variation would seem to be about 80 inches. With too much rainfall all the varieties of cotton with which the station has experimented grow too tall, thus making picking difficult and increasing the cost of harvesting.

The practical control of the bollworm may be accomplished by pruning back the whole field at the close of each picking season and burning all the rubbish promptly. The larvæ and pupæ of the bollworm are found in the infested bolls and are destroyed by burning. Pruning interrupts the crop of bolls as completely as a new planting where the cotton is treated as an annual. It is necessary to prune not only to keep down damage from bollworms but also to hold the plants in proper form; otherwise cotton grown as a perennial attains a size and shape which renders picking difficult. By proper pruning and pinching the terminal buds, it has been found possible to increase greatly the number of lateral branches and to hold the plants within a proper size. Growth from pruned plants is considerably more rapid than from seed, and the yield of such plants is larger than from seedlings the first year. It is barely possible, therefore, that in the extreme southern portion of the cotton belt of the South the same method might be used, provided that the pruning is done low and the stumps protected from the winter frosts by mulching. Upland cotton does not ratoon as promptly, however, as Caravonica and Sea Island.

The danger of hybridization if different cottons are grown in close proximity is apparently greater than has usually been stated. On the station grounds each variety was grown in an isolated spot, at least 300 yards from any other variety. In this way it was possible to make seed selections from year to year with reasonable assurance of success and purity of strain. A peculiar type of Caravonica cotton has developed in which the lint is unusually harsh and strong. This seems to be particularly well suited for mixing with woolen goods, and reports received on samples of the lint indicate that it will be readily bought for that purpose. The latest quotations on lint of cotton samples, which the station has submitted to buyers and cotton graders, are 40 cents for Sea Island, 28 cents for Sunflower, and 25 cents for Caravonica.

MISCELLANEOUS.

The results from the introduction of Japanese rices have not been completely satisfactory. Samples of milled rice submitted to various individuals supposed to be judges of the milled product have brought various opinions which are not quite in harmony. A few have stated

that rice grown in Hawaii from seed imported from Japan is equal in every way to imported Japanese rice. Others have rated it as inferior to the imported rice or as differing from it in certain culinary or other properties which are hard to define, and on which the different individuals to whom the rice was submitted did not agree. The yield of the Japanese rices is satisfactory. There is a general depression in the rice industry in Hawaii, largely due to the preference of the Japanese for the rice imported directly from Japan, and to the further fact that only Chinese labor is available for work in the rice fields and that this labor is scarce and demands an increasing wage. These facts, combined with the high rentals (from $25 to $40 per acre annually) which the rice growers pay for their land, make it difficult to obtain a profit from growing rice.

As a result of experiments with broom corn it has been found that a good quality of brush can be produced in Hawaii, somewhat superior to that grown in California and nearly equal to that obtained in the Central States. A broom factory has been established which can use more brush than is now produced in Hawaii. A number of rice growers and others are beginning to plant this crop in order to supply the local demand. Little difficulty has been experienced in growing broom corn, except in the occasional attacks of plant lice.

There is an increasing demand for leguminous crops for a great variety of purposes. The sugar planters are looking for suitable legumes to grow between the rows of cane for controlling weeds and as a source of nitrogen. Dairymen and ranchers have use for all of the leguminous crops which they can produce for feeding green. The pineapple growers need a suitable legume as a rotation crop and orchardists as a cover crop. For dairy purposes alfalfa, jack beans, and cowpeas are perhaps the best legumes. In some of the pineapple districts pigeon peas have proved superior to all other legumes as a rotation crop. The station is testing all legumes which can be considered as suitable for Hawaii in various locations on the different islands, and the results of the experiments are quickly adopted by the planters and farmers.

Corn is not produced in sufficient quantities to supply the local demand. On one of the larger ranches about 1,400 acres of corn were grown this year, with an average yield of about 35 bushels per acre. All this corn, however, is used for feeding on the ranch. Smaller plantings are being made on other ranches with satisfactory results, but without adding any to the supply of corn on the market, since it is all used in feeding beef cattle and horses. A number of farmers have engaged in corn raising to supply corn for the horses and mules of neighboring plantations. The only serious difficulty in raising corn in Hawaii is of an entomological nature. A bulletin on corn

insects was prepared during the year. A variety of flint corn known as Yellow Creole and recommended as being resistant to corn insects in Louisiana is being tested out, with promising results.

During the year the following publications were issued by the station:

Bulletin No. 21. A Study of the Composition of the Rice Plant.
Bulletin No. 22. Insects Attacking the Sweet Potato in Hawaii.
Bulletin No. 23. Leguminous Crops for Hawaii.
Bulletin No. 24. The Assimilation of Nitrogen by Rice.
Bulletin No. 25. The Avocado in Hawaii.
Press Bulletin No. 27. Use of Insecticides in Hawaii.
Press Bulletin No. 28. Peanuts in Hawaii.
Press Bulletin No. 29. The Management of Pineapple Soils.
Press Bulletin No. 30. Killing Weeds with Arsenite of Soda.
Pamphlet on Taro, in Hawaiian.
Pamphlet on Bananas, in Hawaiian and Portuguese.
Pamphlet on Grapes, in Portuguese.
Pamphlet on the Grazing Industry, in English.

REPORT OF THE ENTOMOLOGIST.

By D. T. Fullaway.

This report covers the periods from July 1 to August 15 and from January 1 to May 15. The entomologist was absent on leave from August 16 to December 31, and on May 16 was transferred to the experiment station at Guam. The routine work of the office, however, was adequately attended to throughout the year and the collections were maintained and much material added. Numerous inquiries regarding destructive insects and remedies therefor were answered by letter or given personal attention.

The investigation of the insects affecting cereal crops, begun the previous year, was continued, and a part of the results are to appear in a later bulletin of the station.

The growing interest in leguminous crops for fodder or soil improvement induced the entomologist to give some attention to the destructive insects of the commoner legumes. The following notes cover observations on the insects attacking the pigeon pea (*Cajanus indicus*), cowpea (*Vigna catjang*), jack bean (*Canavalia ensiformis*), velvet bean (*Mucuna pruriens*), soy bean (*Glycine hispida*), peanut (*Arachis hypogæa*), sweet clover (*Melilotus officinalis*), and alfalfa (*Medicago sativa*). More attention was given to pigeon pea than to the other mentioned crops and, while the list is admittedly not complete for all of these plants, it indicates in a general way what the agriculturist has to contend with in the cultivation of legumes.

NOTES ON INSECTS ATTACKING LEGUMINOUS CROPS.

Leguminous crops are subject to attacks of cutworms and army worms, especially in the winter and spring or on irrigated land. Large fields of alfalfa are sometimes devastated by the army worm, *Heliophila unipuncta*, before it can be brought under control by its natural enemies. Extensive plantings of jack beans have been laid waste by another common army worm, *Spodoptera mauritia* (fig. 1). Swezey records *Spodoptera exigua* from peas and beans, and the writer bred *Heliothis obsoleta* on pigeon pea. One enterprising farmer checked an attack of army worms by flooding his fields. The caterpillars, floating on the water or caught in the meshes of

stranded vegetation, were greedily devoured by mynah birds. Cutworms and army worms are usually kept in check by their parasites—the tachinid flies, *Frontina archippivora* and *Cheatogædia monticola*, the ichneumonid, *Ichneumon koebeli*, and birds. It is, however, sometimes advisable to protect fields from cutworms by spreading out, near the plants, poisoned bait, consisting of arsenic and bran, with a small amount of sugar or molasses to moisten the mixture.

The foliage of legumes is often badly eaten by certain leaf-rollers, *Omiodes monogona* (fig. 2), *Amorbia emigratella* (fig. 3) and *Archips postvittanus*, and by the looper, *Plusia chalcites*, but the damage they inflict is apparently not great except in the case of *Omiodes monogona*, which, so far as is known, feeds exclusively on legumes. It, however, is subject in turn to the attacks of parasites which keep it fairly well in check. *Limnerium blackburni* has been bred from it by Mr. Swezey, and the writer bred *Chalcis obscurata* from the pupæ.

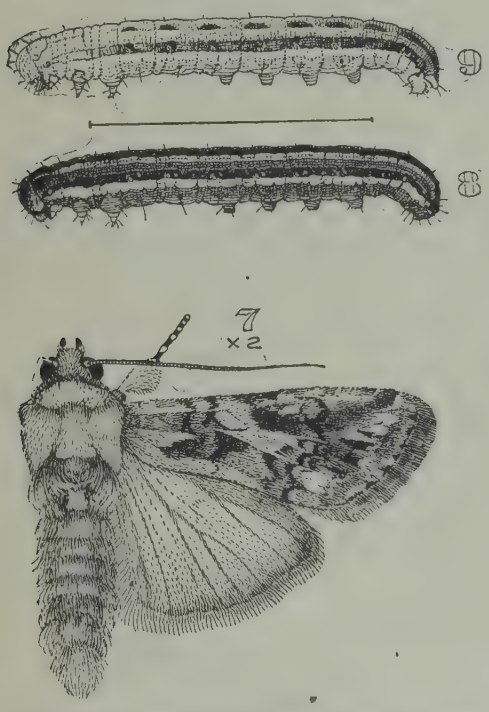


FIG. 1.—*Spodoptera mauritia:* Larva and adult.

Plant-lice or aphids are usually found on cultivated legumes and are likely to affect the growth seriously, especially in the winter months. Some legumes seem to suffer more than others, notably the cowpea, which sometimes becomes so badly infested that it is impossible to get a good stand. The species which attacks legumes is thought to be *Aphis gossypii*. When the infestation is bad, the dark form, ranging from dull purplish-black to shining piceous black, prevails. It is often necessary to spray legumes threatened with aphid injury with tobacco decoctions and nicotine solutions, which are fairly cheap and effective agents to use in such cases. Aphids are fairly well kept in check most of the time by ladybird or coccinellid beetles, of which there are numerous introduced species present. The larvæ of the syrphid fly, *Xanthogramma grandicornis*, and of the agromyzid, *Leucopis nigricornis*, also prey on aphids and are usually found where aphids are abundant.

The common representative of the scale insects (Coccidæ) found on legumes is the cottony cushion or fluted scale, *Icerya purchasi*, which, while normally controlled by *Novius cardinalis*, sometimes becomes very abundant and does considerable damage before the ladybirds become numerous enough to clean it out. Pigeon pea and

peanuts are usually more badly infested than other legumes. Cutting and destroying all badly infested branches as soon as noticed is recommended. When abundant the scale insects are usually massed together on the stems and very little work is involved in thus getting rid of them. Mealy bugs, embracing several species, infest legumes,

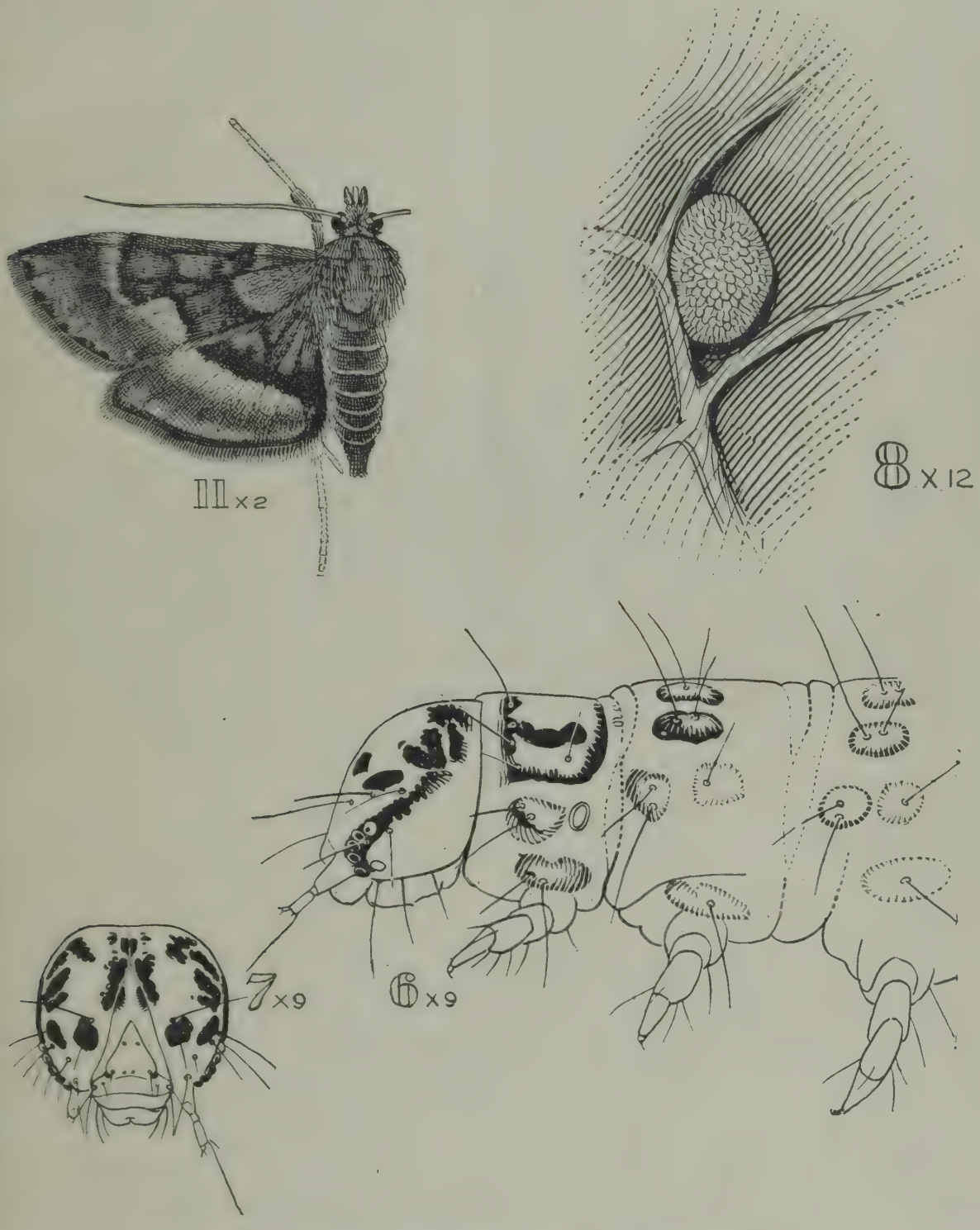


FIG. 2.—*Omiodes monogona:* Adult, egg, and larva.

notably *Pseudococcus longispinus*, *P. citri*, *P. virgatus*, and *P. fiamentosus*, but do little apparent damage and are usually controlled by their parasites and predators. The first three species have been noticed on pigeon pea and the last more especially on clover. The flat scale, *Saissetia oleæ*, is common on pigeon pea and crotalaria.

The leaves of most of the cultivated legumes and some other plants as well are mined by the larva of a small agromyzid fly, determined by the late D. W. Coquillett, of the Department of Agriculture at Washington, as *Agromyza diminuta*. The wandering track of the miner in the mesophyll is indicated by a rather broad line of transparent green which contrasts boldly with the darker shade of the leaf.

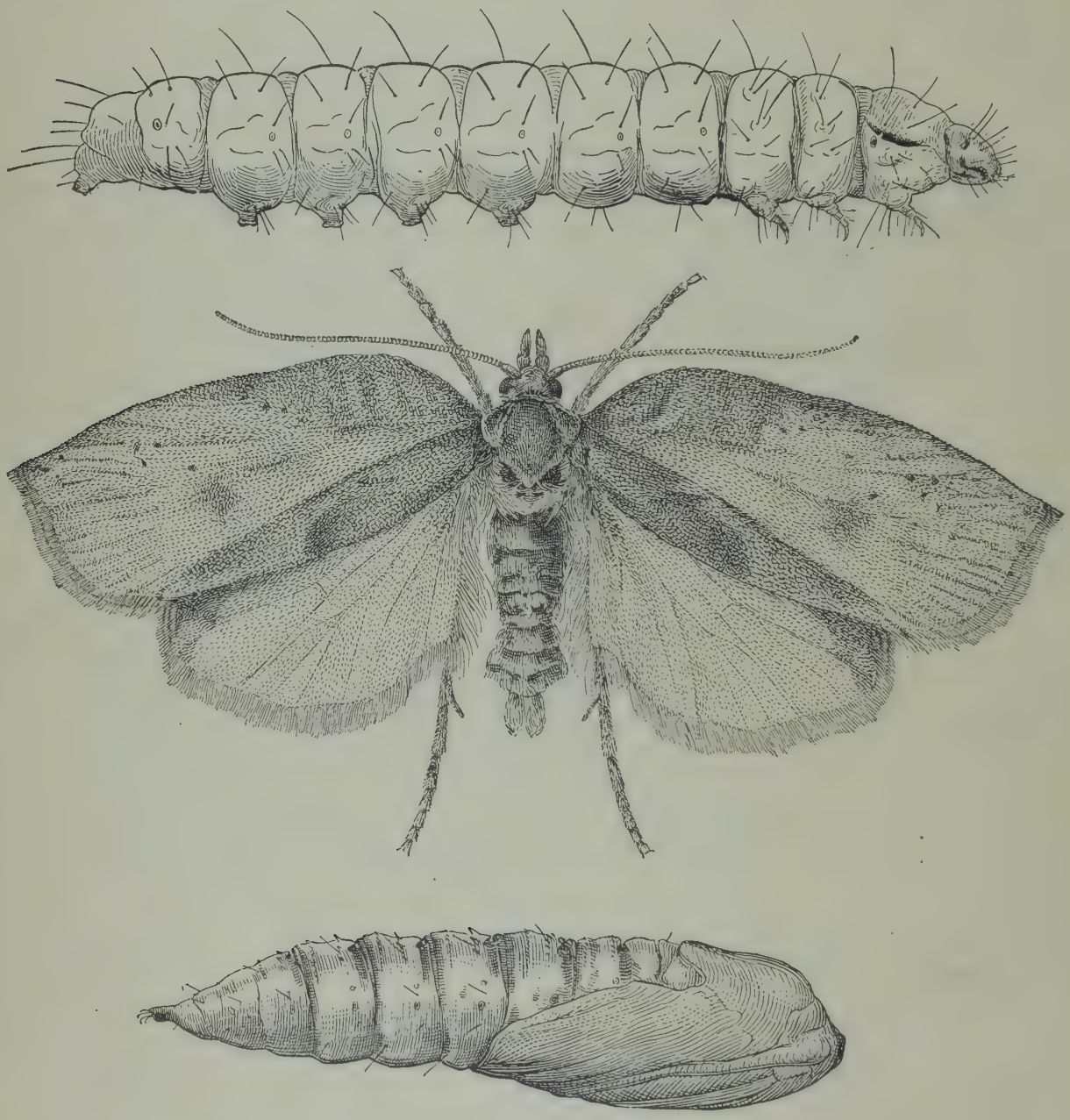


FIG. 3.—*Amorbia emigratella:* Larva, moth, and pupa.

The foliage is often badly shattered, and if the mining is extensive, one surface of the leaf will usually split when the leaves become dry and brittle. This miner, however, will probably never be a serious pest, as it is effectively parasitized by the eulophids, *Omphale metallicus* and *Pediobius* sp. The adult fly is the pretty little black and yellow two-winged insect often seen hovering about the foliage of legumes. It has been bred from leaves of cabbage, geranium, and

nasturtium as well as from the following legumes: Jack beans, cowpeas, alfalfa, and clover. The larva, when mature, leaves the leaf by breaking through the epidermis and enters the ground to pupate.

Probably the most injurious insect attacking legumes is the one designated the bean pod borer, the larva or caterpillar of the common blue or hairstreak butterfly *Lycæna bætica*. This is a widely distributed pest, not, however, found in America. Its habitat as given by Meyrick is western France (an occasional emigrant to England), southern Europe, central and southern Asia, Africa, Australia, and the Pacific Islands. It attacks the pods of various legumes, devouring the growing seeds. The pigeon pea, according to my observation, is more severely attacked than other legumes, but the crotalarias and garden peas and beans are usually infested. I have also found the eggs on jack beans and cowpeas. The following is an account of its life history:

The eggs are laid singly, on the outer parts of the flower (sepals and bracts), on the leaves, and on the stems. They are pale green when fresh, depressed spheroidal, 0.5 millimeter in diameter, 0.27 millimeter high; openly reticulate, the network formed by well-developed ridges; tuberculate at the angles of intersection. The reticulation is more closely drawn around the micropyle, which lies in a shallow depression. The base is rather flat and rather faintly sculptured.

The larva emerges through a hole made in the top and at the time of hatching is about 1 millimeter long, body yellowish green, head black, cervical shield conspicuous, transversely rhomboidal, fuscous, anal shield black, more or less cylindrical, tubercles black, minute, each with a seta, arranged in longitudinal rows, 1 close to dorsal line and more or less posterior in the segment, 2 a little more removed and anterior, larger than 1, 3 above the spiracle, 4 and 5 below, 4 anterior, 5 posterior in the segment, 6 and 7 beneath, hairs longer laterally and caudally. The larva moults three times during the course of its growth. When full grown it is about 14 millimeters long, 4.5 millimeters wide, onisciform in shape, the segmentation distinct. The head is small, about 1 millimeter wide, retractile and usually hidden beneath the first segment, rounder in front, slightly depressed, testaceous, lower margin of ocelli broadly, upper margin narrowly, labrum, anterior margin of interlobular area and borders of lobes entirely black. The body is plump, light green, with the following claret markings, the colors varying greatly in intensity; dorsal line, beginning at anterior margin of third segment and extending to tip, a deep claret, oblique claret suffusion on each segment, midway between dorsal line and spiracles, pale claret suffusion laterally along spiracular line. Thickly covered with irregular blackish and whitish tubercles bearing short brownish hairs; more

closely crowded on eleventh and twelfth segments. Legs brownish with black tips; spines on prolegs claret colored, lateral line and under side of body very pale green. Three last segments depressed, linguiform. Hairs longer on first and second segments and under side of body. The length of the larval stage is about 18 days.

The pupa is about 10 mm. long and of the usual lycænid form. Outline from above irregularly oval, greatest width 4.5 mm., at fourth abdominal segment. Dorsum rounded, venter more or less flat, thorax gibbous, a large well-formed gibbosity dorsally and smaller protuberance laterally. Cephalic margin truncate, slight constriction at first abdominal segment, body gradually contracting beyond fourth segment. Luteo-testaceous and speckled with fuscus black, also black markings as follows: A large one on dorsal line of head, several subdorsally and laterally on thorax, an irregular double line on abdomen above spiracles, continued on venter to sixth segment, dorsal claret line from anterior margin of third abdominal segment to posterior margin of seventh. The spiracles are small, narrowly elliptical, margins black. Wing and antennal cases reaching posterior margin of fifth abdominal segment, the former broadly rectangular. Short capitate hairs on head. Cremaster inconspicuous. The length of the pupal stage is 11 to 12 days.

Moth.—"Length 26–30 mm. Wings fuscous, in ♂ suffused with purple-blue except on termen, in ♀ on basal half only; hind wings with long linear terminal projection on 2, and a blackish subterminal spot on each side of it. Wings beneath pale brownish, with irregular partly connected white striæ; hind wings with white posterior fascia, and two black partly orange-edged spots, marked with pale metallic green-blue, before termen above tornus."[1]

The dry pods and seeds of legumes are attacked in storehouses and somewhat in the field by certain insects which habitually feed on stored products, notably bruchid weevils. Five species of this family have become established here. *Bruchis chinensis* and *B. prosopis* have bred from seeds of the pigeon pea, *B. chinensis* from seeds of the cowpea, and *B. prosopis* and *Caryoborus gonagra* from seeds of keawe (*Prosopis juliflora*). The prinid beetle *Catorama mexicana* has been bred from seed of the velvet bean and the common coffee bean-weevil (*Araecerus fasciculatus*) from pigeon pea seed stored and in the field. (Fig. 4.)

The following minor pests have been observed: A thrips determined by Mr. E. M. Ehrhorn as *Trichothrips nigricans* is abundant in the blossoms of pigeon pea. *Xiphidium varipenne* probably sometimes feeds on legumes, but is largely carnivorous in habit. A red spider (*Tetranychus* sp.) has been noticed on the foliage. The broken stems are bored by bostrychids.

[1] Meyrick. Handbook of British Lepidoptera. London, 1895, p. 347.

In connection with the work outlined above some observations were made on the capsid bug *Hyalopeplus pellucidus*, which is commonly found on pigeon pea as well as on many other economic plants, notably cotton and hibiscus. It has usually been thought that this insect is at times predaceous, and having it on the authority of the late Mr. Kirkaldy and others, the writer so described it in a bulletin on cotton insects published several years ago.[1] But after taking the greatest pains to discover any predatory inclinations, he is inclined to think it nourishes itself entirely on plant juices. It has repeatedly been observed in all stages feeding on plants.

Kirkaldy[2] describes the ultimate and penultimate nymphal instars, but nothing is said of the egg or earlier stages. Several gravid females captured in the field and confined in breeding jars oviposited

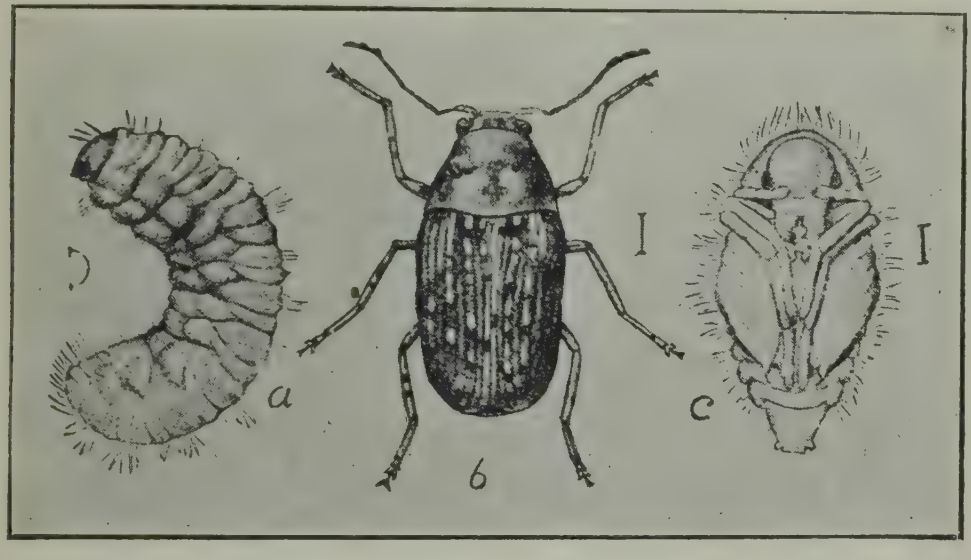


FIG. 4.—*Aræcerus fasciculatus:* Larva, beetle, and pupa.

a few days later and the process of egg laying was carefully noted. The eggs are inserted singly in the stems or buds, one female laying probably 15 or 20. They are about 1.4 mm. long, smooth, pearly white, and flattened cylindrical, slightly curved, with a spur outwardly on lower edge, which forms the scar. The egg stage occupies approximately 10 days. There are supposedly five nymphal instars as in other bugs, but only four were observed by the writer, the first apparently being missed. There is little difference in the earlier stages from those described by Kirkaldy, except in the shape of the body and the comparative length of body, beak, and antennæ. In the second instar the body is 1.5 mm. long, the antennæ 1.75 mm., second and fourth antennal joints subequal, third nearly 2, and the second $2\frac{1}{2}$ times the first. The labium reaches nearly to the apex of the body which is covered with long fuscous yellowish pile. The

[1] Hawaii Sta. Bul. 18, p. 25.
[2] Proc. Hawaiian Ent. Soc., 1 (1907), pt. 4, p. 159.

pronotum is a little longer than the head and a little less than its apical width. The hind margin is subequal to the apical margin; scutellum indistinct.

In the third instar the body is 2.5 to 3 mm. long, the antennæ 2.5 mm., the relative length of joints very much as in later stages. The labium reaches the apex of the fourth sternite. In this and the preceding stage the markings are more extensive than indicated by Kirkaldy. The purplish-red or sanguineous medium percurrent or laterally sinuate lines on head reach slightly beyond the thorax, and on the abdomen on each side are five more or less distinct percurrent lines of sanguineous spots reaching to the apex, where they are more pronounced than in front. In this stage the wing bugs appear. The total length of nymphal life is 14 days.

THE MEDITERRANEAN FRUIT FLY.

The recently introduced Mediterranean fruit fly (*Ceratitis capitata*), which was first noticed in the summer of 1910, is spreading rapidly on Oahu and gives every promise of becoming a serious fruit pest here as elsewhere. It has been bred so far from oranges, limes, pomelos, peaches, mangoes, guavas, and peppers. Citrus fruits and peaches around Honolulu seem to be generally infested. The insect, which is probably a native of Africa, but now widely distributed by commercial operations, resembles in a general way the melon fly, but is much handsomer in appearance. Its habits are very similar to those of the melon fly, the eggs being laid beneath the surface of fruits by means of the sting-like ovipositor. Infested fruits often show discolored spots on the surface. The maggots hatching from the eggs develop in the interior of the fruit, which gradually becomes putrid. Fruit infested on the tree usually falls early to the ground and the larvæ when full grown leave the fruit and enter the soil to pupate. The life cycle is said to cover about one month.

Little can be suggested in the way of remedial measures, as the fly reproduces itself so rapidly and so abundantly that, in countries where conditions are less favorable for its multiplication than they are in Hawaii, it is impossible to prevent great damage by the fly to the fruit crops which it infests. In South Africa it is partially controlled by the timely application of a light sprinkling of poisoned bait, consisting of 2 pounds of arsenate of lead and 25 pounds of sugar to 40 gallons of water, on the trees. In Hawaii, however, as pointed out by Dr. Perkins, the hive bee must be taken into consideration, many of which would also be killed by the poison, especially at such times as the algaroba and other flowers visited by the bees are out of bloom.

REPORT OF THE HORTICULTURIST.

By J. E. Higgins.

One of the chief lines of work that has occupied the attention of the horticultural department during the year has been on the avocado. Among other aspects of the subject, special attention has been paid to propagation, spraying for the control of a fungus disease and for a caterpillar, and also the study of varieties.

AVOCADO INVESTIGATIONS.

Much attention has been given to the propagation of the avocado by budding, both at the station and elsewhere. Investigations have now been carried far enough so that methods of budding have been devised which are quite satisfactory. Some of the difficulties which have been encountered have been in the securing of good bud wood and the starting of buds into growth. Some old trees that are doing well in fruit production fail to produce a reasonable number of good buds. In the case of these it is sometimes necessary to prune a part of the tree rather severely to induce a growth of suitable bud wood. It has been found best to force newly set buds into growth by the incomplete girdling of the branch about 6 inches above the bud. It has not been very satisfactory to lop the avocado trees, as has been done with citrus. It has also been found to be an advantage to cover the entire bud with a wax bandage at the time of budding. With such precautions and working with good stocks, from 75 to 90 per cent of the buds may be expected to grow.

The spraying experiments, which have been carried on largely by Mr. Hunn, have been designed to determine the best methods for the control of a fungus disease which has been called "rusty blight" because of its effect upon the foliage, and also for the control of a leaf-folding caterpillar, *Amorbia emigratella*. The effect of some of these sprays is also being noted upon the avocado mealy bug, *Pseudococcus nipæ*. The four sprays used have been Bordeaux mixture and arsenate of lead, Bordeaux mixture and lime resin, self-boiled lime-sulphur and arsenate of lead, and a brand of commercial lime-sulphur and arsenate of lead, thus using a combined insecticide and fungicide.

Mr. Hunn has made an extensive study of the varieties of avocados growing in and about Honolulu. Between 65 and 70 varieties have been carefully studied and described. A number of these have

already been budded into the trees in the avocado orchard. This orchard is making normal growth, and a few of the trees are coming into bearing. These phases of the avocado work, as well as others, have been reported upon quite fully in a bulletin recently issued upon the avocado in Hawaii.[1]

Detailed outlines have been devised by Mr. Hunn for the description of varieties of avocado, papaya, mango, and hibiscus.

PAPAYA INVESTIGATIONS.

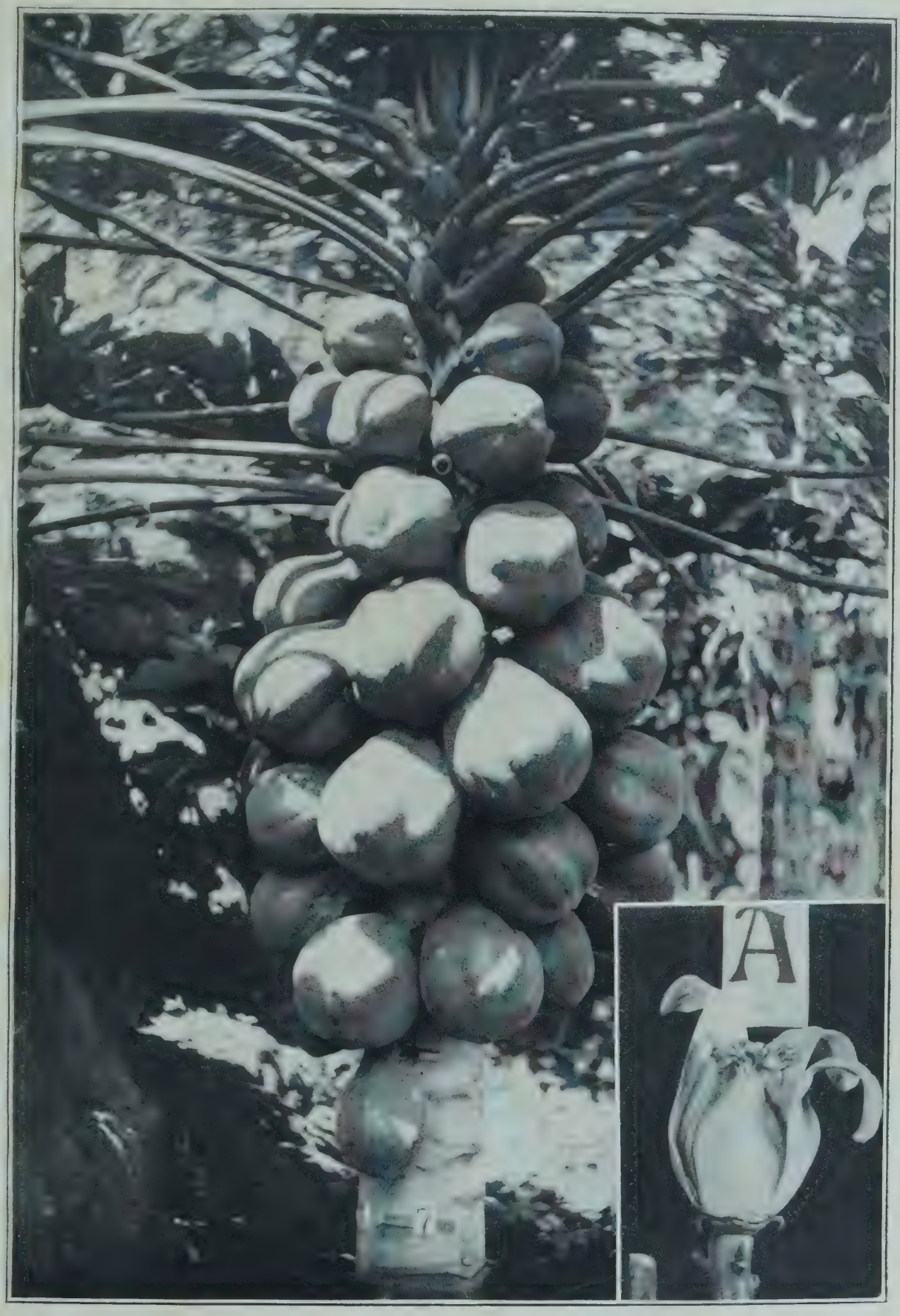
BREEDING.

The papaya investigations have been continued through the year. The work has included breeding, pruning, thinning, and shipping, and has been carried out by Mr. Valentine S. Holt, assistant in horticulture. The ultimate aim of a part of this undertaking is to work out methods for the breeding of varieties of desired qualities that can be depended upon to reproduce themselves with reasonable accuracy from seeds. It will be understood that there is no means available for the propagation of the papaya by asexual parts, as cuttings, buds, scions, etc., hence seed varieties must be established by methods probably similar to those used in breeding varieties of vegetables and flowers which are not propagated by budding and grafting.

The report for the year 1910 indicates the progress of the work to that date. It may be recalled that attention was then directed to the two most distinct forms of the papaya—the diœcious and the monœcious, with many apparently intermediate forms. Before entering upon a discussion it may be well to review this situation and note the significance of certain terms which have been adopted to designate the plants and flowers which enter into the work. Plate I shows the pistillate tree and flower representing the female element of the diœcious type. This diœcious type is the best-known form of the papaya. This pistillate tree, as is well known, produces the fruit. Plate II, figure 1, shows the staminate tree and flower of this diœcious type and represents the male element. This tree also produces occasionally a flower containing both stamens and pistils, and therefore capable of producing fruit. These hermaphrodite flowers, however, are frequently distorted, and most staminate trees fail to produce them. Plate II, figure 2, shows a tree and also a larger view of the flower of the monœcious type. It will be seen that the stamens are to be found attached to the inner walls of the corolla and quite close to the stigma.

Bearing in mind these distinctions, it may be recalled that in the last annual report a suggestion was then offered to the effect that it would probably be well to discontinue the use of the diœcious type,

[1] Hawaii Sta. Bul. 25.



PISTILLATE PAPAYA TREE AND FLOWER OF THE DIŒCIOUS TYPE.

FIG. 1.—STAMINATE PAPAYA TREE AND FLOWER OF THE DIŒCIOUS TYPE.

FIG. 2.—PAPAYA TREE AND PERFECT FLOWER OF THE MONŒCIOUS TYPE.

except, possibly, in combining it with the monœcious, because of the unknown and probably unknowable characters of the staminate plant. But some of the papayas of the diœcious type have certain desirable characters which it would be an advantage to combine with a monœcious variety. This opens the whole question as to the possibilities of close and cross pollination in the papaya. In order to test this matter, 16 different possible combinations of pollen and stigma were tested, and some light has been obtained on the subject. These possible cross and self fertilizations were as follows:

(S)[1] 1. Perfect monœcious flower with its own pollen.

(U) 2. Perfect monœcious flower with pollen from a staminate flower from the same cluster.

(U) 3. Perfect monœcious flower with pollen from a staminate flower of another cluster on the same tree.

(S) 4. Perfect monœcious flower with pollen from a perfect flower on another monœcious individual.

(U) 5. Perfect monœcious flower with pollen from a staminate flower of another monœcious individual.

(S) 6. Perfect monœcious flower with pollen from a perfect flower on the so-called "male tree."

(U) 7. Perfect monœcious flower with pollen from a staminate male flower on the so-called "male tree."

(S) 8. Pistillate (diœcious) flower with pollen from a perfect flower of monœcious type.

(U) 9. Pistillate (diœcious) flower with pollen from a staminate monœcious.

(S) 10. Pistillate (diœcious) flower with pollen from a staminate tree ("male").

(U) 11. Pistillate (diœcious) flower with pollen from a perfect (hermaphrodite) flower occasionally found on the so-called "male tree."

(S) 12. Perfect or hermaphrodite flower on the male tree with pollen from a perfect flower of the monœcious type.

(U) 13: Perfect or hermaphrodite flower on the male tree with pollen from a staminate flower of the monœcious type.

(S) 14. Perfect or hermaphrodite flower on the male tree with pollen from the staminate flower from the "male tree."

(S) 15. Perfect or hermaphrodite flower on the so-called "male tree," with its own pollen (hand pollinated).

(S) 16. Perfect or hermaphrodite flower on the so-called "male tree," with its own pollen (sealed in sack but not hand pollinated).

Several questions are involved in each of these pollinations. Take, for example, the eighth pollination, or that of a pistillate (diœcious) flower with pollen from a perfect flower of the monœcious type,

[1](S) and (U) refer to successful and unsuccessful crossing.

which seemed perhaps the most promising means of combining any desirable character of the diœcious papaya with the monœcious, and out of this pollination will arise, among others, the following questions:

(1) Is it possible to make this cross?

(2) If this cross is possible, what will be the result in the sex of the progeny? Will there be a certain number of staminate trees and also pistillate and monœcious, or will some of the characters of the diœcious tree and some of those of the monœcious be combined in the offspring?

(3) To what degree will the characters of the female parent be reproduced in the monœcious offspring?

(4) Will it be possible by close pollination to preserve in future generations the monœcious character of certain members of the first generation of offspring if such appear? It will be remembered that the aim is to get back in breeding, as in commercial culture, to the monœcious type.

The work has already gone far enough to give definite answer to some of these questions and some light has been thrown upon others. For example, it can be stated definitely that the first question can be answered in the affirmative. It is perfectly possible to fertilize the stigma of a pistillate flower with pollen from a perfect flower of the monœcious type. Some light has been thrown upon the second question, but from its very nature it would be necessary to conduct a large number of tests extending over several years in order to establish any law governing the proportion of male and female and monœcious types resulting from such crosses. One year is a short time within which to get figures on this question. The striking fact, however, is that in the case of the eighth type of cross the resultants have shown a considerable proportion of monœcious individuals. Some of these resultants are intermediate in certain characters. While they produce flowers possessing both stamens and pistils which mature fruit, the stamens are less definitely located than in the case of the plant which we regard as the normal monœcious type. Plate III, figure 1, illustrates this condition. At "D" may be seen two flowers just beginning to develop into fruit. The one on the right has the stamens placed in the normal manner in the throat of the corolla to which they are attached. The upright one has dropped its petals, but the stamens may be seen still attached to the disk at the base of the ovary. This particular cluster of flowers came from a plant of unknown parentage, but illustrates the meaning of the statement that this flower and fruit are unlike the ordinary monœcious in form. The stamens are variously placed, in some cases being found on the lobes of the ovary. At "B" may be seen

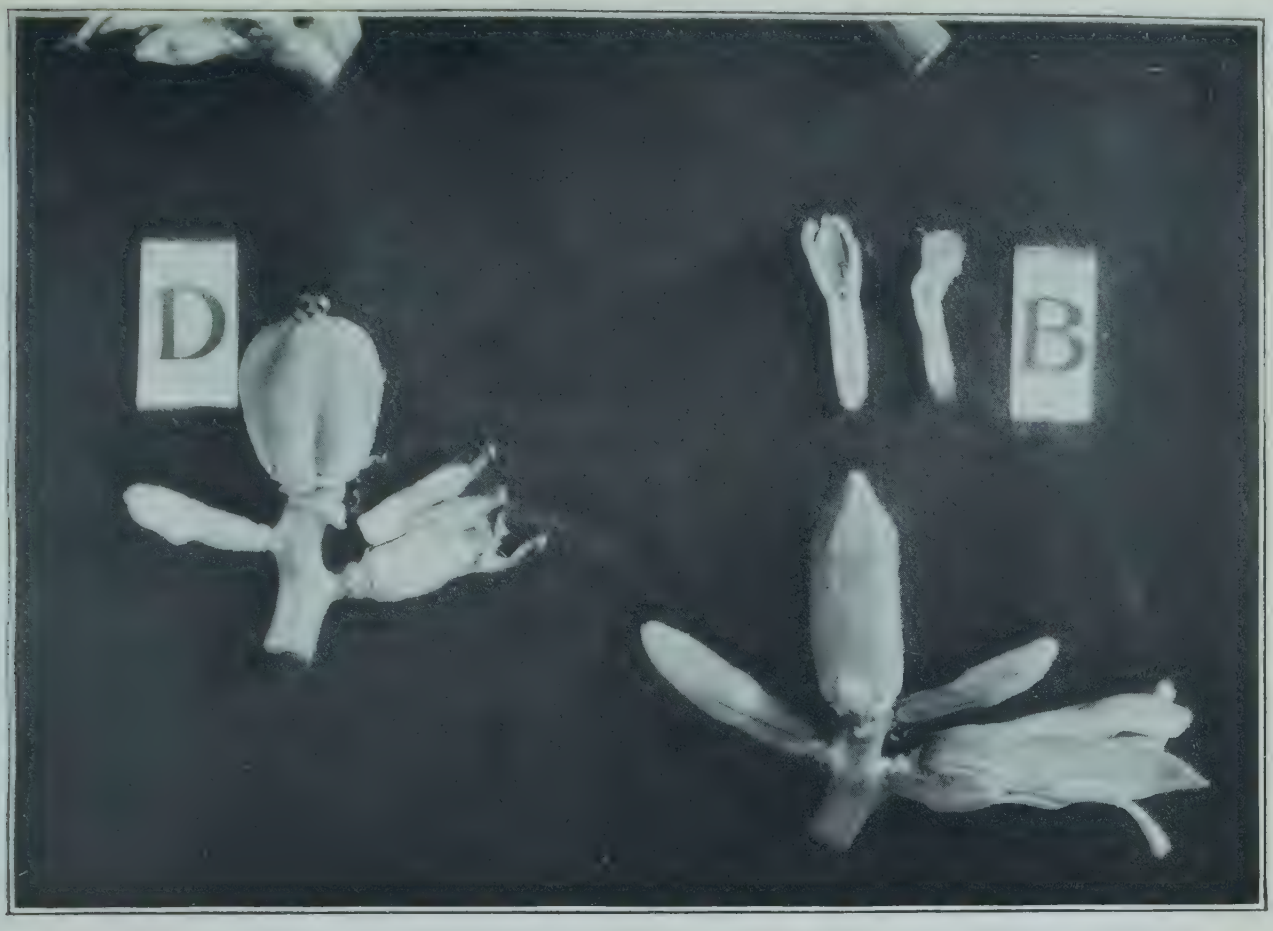


FIG. 1.—PERFECT AND MONŒCIOUS TYPES OF FLOWERS OF PAPAYA.

D. Two forms of perfect or hermaphrodite flowers in the same cluster. The lower flower to the right is of the normal form; the upper has the stamens at the base of the ovary, which is in shape like that of the diœcious type. B. Staminate flower of the monœcious type above; normal cluster below.

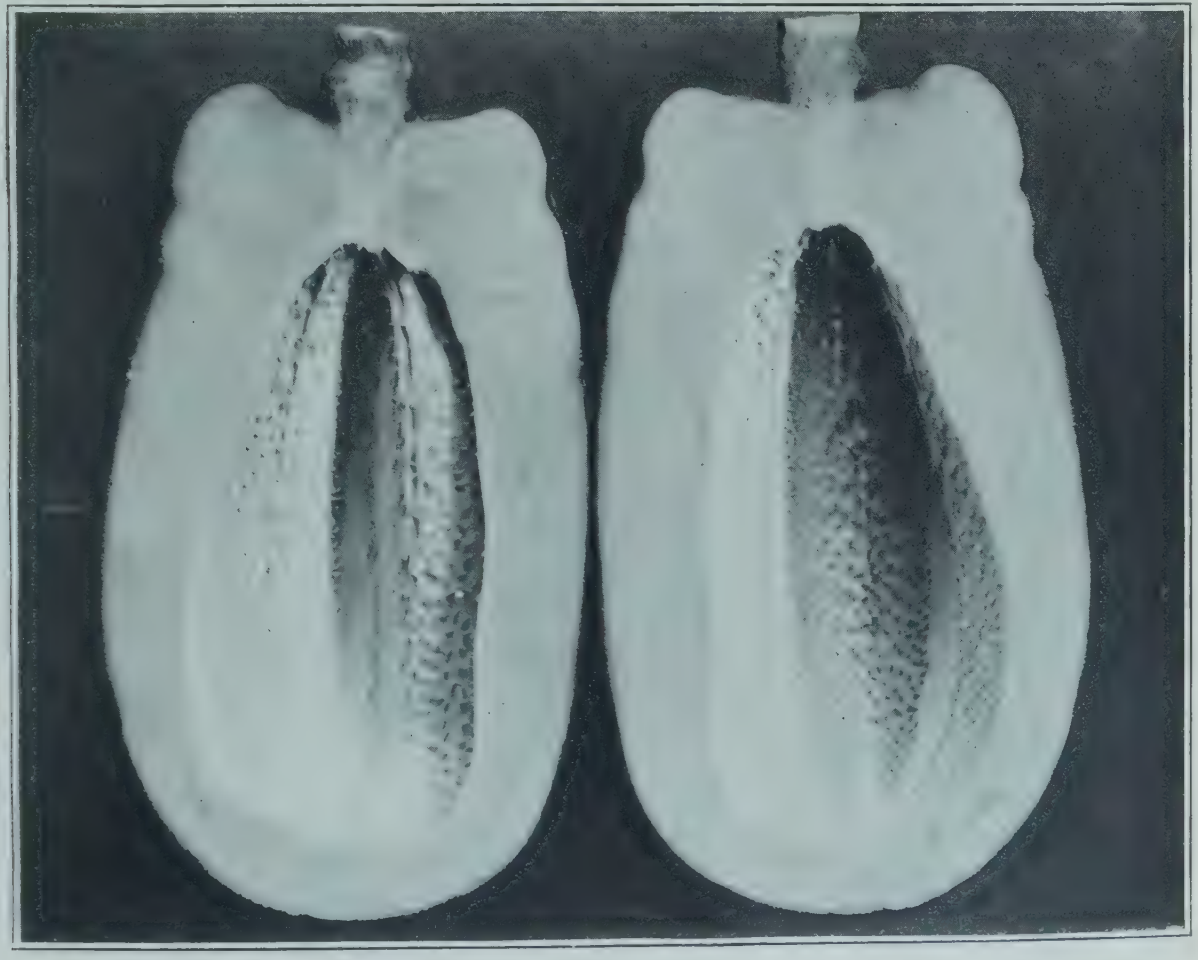


FIG. 2.—A SEEDLESS PAPAYA GROWN FROM AN UNPOLLINATED FLOWER.

the ordinary staminate flower of the monœcious type and below is a normal monœcious cluster.

It has been shown, then, that it is possible to make the cross to which reference was made in the annual report for 1910 and to get a fair proportion of monœcious trees in the offspring. The answer to the third inquiry, which has been raised, namely, to what degree the characters of the female parent will be reproduced in the monœcious offspring, must await the ripening of the fruit and then may be only suggested. The problem involved in the fourth inquiry must remain open for some time.

The same series of inquiries arose regarding the ninth combination where pollen of a staminate monœcious flower was applied to diœcious stigma, and similar questions in relation to the other possible pollinations. In the list of pollinations (p. 27) those which have proved more or less successful are indicated by the letter "S," while those unsuccessful are indicated by the letter "U." It will be seen that the ninth and all other pollinations including the use of pollen from the staminate flower of the monœcious type have failed to fertilize the ovaries. This includes with the ninth, the second, third, fifth, and thirteenth. It would not be safe to conclude from the evidence now in hand that all of these combinations are impossible, but further studies of this pollen must be made.

Setting these aside for the present, therefore, some attention may be given to the result of other pollinations. The latter have been made too recently to have shown much beyond their ability to fertilize. The first and fourth have set fruit in a fair proportion of cases and these fruits probably contain seeds. The sixth has proved successful so far in one instance only. In this one fruit has set, but what the effect has been in seed production can not yet be determined. The same is true of the twelfth. A reasonable proportion of the pollinations of the fourteenth, fifteenth, and sixteenth types have been successful.

The tenth pollination is interesting in showing the effects of breeding within the diœcious type. The progeny of one set of pollinations has been brought to fruit production. None of these plants shows any tendency toward the monœcious type. They include pure pistillate and pure staminate individuals only. This evidence, so far as it goes, is confirmatory of the theory that the monœcious and diœcious types are rather distinct and that the intermediate forms are variants.

Early in the work it was discovered that a certain papaya tree growing on the station grounds was devoid of seeds in all fruits which were examined. It was desired to learn, first, whether this seedless condition is due to lack of pollination; and, second, whether it is possible for the papaya fruit to develop without the fertilization of the ovary. To get some light on these questions a number of

flowers of this tree were hand-pollinated with pollen from a staminate flower of the diœcious type. Several other flowers were sealed in paraffin sacks several days before opening to prevent pollination by natural means. All these flowers, both pollinated and unpollinated, developed into full-grown papayas.

Flowers on other trees have been sealed without pollination, but in most instances have failed to produce fruit, the pistils falling off within a week or two. On some trees, however, it has been found that sealed unpollinated flowers have produced normal papayas, except that they have been without seeds and have been smaller in size than the fruits from fertilized ovaries. (Plate III, fig. 2.)

From the above statements it seems justifiable to conclude, first, that pollination is not always necessary for the production of fruit in the papaya, and, second, that seedlessness in the case of the first tree mentioned above is probably not due to a lack of pollination, since the pollen used in the pollinations was of the type which usually gives good results and also because the flowers of this tree have the same opportunities to become fertilized as those of the surrounding trees which produce fruit containing seeds.

PRUNING.

The papaya tree has some tendency to branch. The branches soon begin to bear fruit. This usually results in the production of a large number of fruits per tree, but they are likely to be small. Experience, therefore, at this station seems to indicate that to get large-sized fruit it is best to prune off these branches when they first appear, allowing the vitality of the tree to pass along the main trunk and develop its fruits.

THINNING OF THE FRUITS.

One of the characters of some papaya trees is to set very many more fruits than there is room for on the trunk. A large number of such trees have been found among the crosses referred to (p. 27) under the eighth type of pollination. Such fruits can never develop normally in size or shape, but crowd each other and thus become distorted. In the case of such trees it has been found necessary to thin the fruits, leaving usually only one fruit to each flower cluster or in the axil of each leaf.

SHIPPING EXPERIMENTS.

Several years ago this station, in connection with other fruit-shipping investigations, made trials of placing this fruit in several markets on the Pacific coast. It was taken to San Francisco and thence as far north as Vancouver, B. C., where a fair proportion of

it arrived in good condition, notwithstanding the lack of refrigeration on the rail journey, unusually warm weather, and delays in transit. It was apparent, however, that there are marked differences in the carrying qualities of papayas from different trees, some being unsuitable for shipment.

At the time referred to the station was not growing papayas in sufficient quantity for shipping tests and the supply available was such as could be found in small orchards supplying the Honolulu market. Recently the trial shipments have been resumed in a very small way by sending to San Francisco a few papayas grown at the station grounds. The purpose was to further test in general the possibilities of placing this fruit in the mainland markets and in particular to make trial of the carrying qualities of some varieties that are being grown at the station.

This work was undertaken prior to the recent quarantine regulations of the State of California, which temporarily prohibit the importation into that State of all fruits from Hawaii except bananas and pineapples. The fruit fly has not been found in the papaya, and it may be demonstrated that it does not injure this fruit. Until this matter is settled, no shipping of papayas to the mainland can be done; but the results of the work are herewith published for the significance which they have upon the papaya as a shipping fruit wherever grown or marketed.

The fruits were forwarded in refrigeration per steamship *Sierra*, sailing from Honolulu on April 19 and arriving in San Francisco on April 25. All the fruits were beginning to ripen when they were gathered from the trees, most of them exhibiting only the first indications of yellowing. They were gathered on the day preceding that of the sailing of the ship and were packed in excelsior in open crates, each fruit having been wrapped in paper.

These experiments were upon a small scale, but so far as they go their indications are the most favorable of any papaya shipments that have been made from this station. The reports received from those to whom the fruits were sent indicate that with the exception of one fruit the papayas were too green to be eaten on arrival in San Francisco, and a period of 5 to 12 days elapsed before they became sufficiently ripe in ordinary air temperatures. Considerably less time than this would be sufficient to distribute the fruit through the various channels to the consumer and would also offer the opportunity for a permanent supply with steamers sailing not more frequently than at present. Peaches, cherries, and other fruit that would not stand so long a period are shipped by carload lots across the American continent.

The indications are that, as the papaya industry develops, in Hawaii or elsewhere, there will prove to be at least three important factors in the successful placing of these fruits in distant markets. One of these is on the side of production. It will be necessary to grow varieties that have good carrying qualities. Papayas differ greatly in this respect, and one of the problems upon which the station is now working is to select, segregate, and if possible improve varieties that possess these qualities in a high degree. The experiments indicate that some degree of success has already been attained. In order to make the work successful in the largest way, it will be necessary not merely to select trees of the desired qualities but to establish varieties so that they can be depended upon to reproduce their characters.

The second factor in successfully shipping papayas to the mainland is on the side of packing. The fruits must be gathered at the right time and must be carefully handled and packed, wrapping each fruit in paper and surrounding it with sufficient packing material to prevent bruising and yet not interfere with refrigeration. The crate should be open so as to permit the rapid cooling of the fruit, which should be put into refrigeration as soon as possible after picking.

The third factor pertains to the proper distributing of the fruits. Papayas are unknown on the mainland except to the few who have visited Hawaii or some other tropical land. If placed in the usual wholesale market, the fruit would probably rot before a buyer would appear who knows the papaya. Therefore some other means of finding the consumer and of developing the taste among those unfamiliar with the fruit must be devised. In some markets there are dealers who make a specialty of handling rare and unusual fruits, and they have their special class of customers. Where such dealers are not to be found it would seem best to begin with large hotels and fashionable clubs and restaurants. With these special arrangements could be made to receive small shipments regularly and thus build up a market.

MISCELLANEOUS WORK WITH PAPAYAS.

Other miscellaneous work with the papayas during the year has included the combating of insects, including cutworms, the small larva of the genus Amorbia, which hides among the flowers and emphasizes the need of thinning them, and black and green aphids on fruits; and the collecting and drying of the milky juice of the fruit which has been carried on only in a preliminary fashion.

INVESTIGATION OF BANANAS IN HILO AND OLAA, HAWAII.

Early in December a letter was received from Hon. L. A. Thurston, general manager of the Hilo Railroad, reporting certain difficulties

with the Bluefields banana in Hawaii. It was stated that this variety of banana was failing of success because of the breaking off of the pseudostems and the falling of bunches. It was also stated that the same difficulty was found with another banana which had been introduced into Hilo from the district of Hamakua, probably 12 or 15 years ago, and is reported to have been brought to Hamakua by the captain of a ship which anchored off this coast. This latter variety has been regarded by some observers as being identical with the Bluefields.

In view of the recent revival of interest in the banana industry it was deemed important to investigate this matter. The horticulturist proceeded to Hilo on December 13, returning December 17.

It was found that a very large percentage of the Bluefields plants in some localities broke or bent over; in other places this was not so common. There appeared to be several causes at work contributing to this trouble. It does not appear to be due to any inherent weakness of the variety; nor, we believe, to any lack of adaptability to Hawaiian conditions. Some of the causes at work appear to be as follows:

(1) Close planting. The practice in vogue in the planting of the Chinese and other small growing varieties had been adopted for the Bluefields. It was found that they are being planted as close as 6 by 6 feet in some cases, and the widest planting found was about 10 by 10 feet. This variety has been found to do best at 12 by 15 or as wide as 15 by 15. The close planting makes too dense a foliage and the plants become thin stemmed and spindling, as is the case with most plants that are crowded and reaching upward in the effort to get light.

(2) The bunches are left upon the plant until they become extremely large and heavy. On one plantation the writer was informed that from 90 to 100 pounds was the average weight of the bunch when cut. On another plantation the information was given that one bunch had weighed as high as 140 pounds. It is the custom in Hawaii to leave the bunches on the plants until they are almost ripe. In this way they acquire their full flavor, but in commercial growing for export such bunches would decay before reaching the market. This variety of banana, as grown in the West Indies and Central America, is cut some time before it has attained its full weight.

(3) Lack of pruning. It was found that the pruning off of the dead leaves has not been practiced. These are allowed to fall back against the pseudostem. This adds to the darkness in which the pseudostem is confined and it also retains moisture. It appears also that this may be a contributing cause of the failure of the plant to sustain its load of fruit.

SEARCH FOR BANANA DISEASE.

A search was made for plants which might show indications of the banana blight, now prevalent in the West Indies and Central America, which is believed to be due to a Fusarium. No certain evidence of this disease was found. In one field the plants were reported to have died back in a manner somewhat similar to that of bananas affected with Fusarium. These plants, however, were growing in grass and had not the opportunity to flourish. Some of the plants showed discolorations in the pseudostem which looked somewhat suspicious. Material was collected from a number of plants which showed more indications of the disease than any others, and this material has been forwarded to the Department of Agriculture in Washington to be submitted to specialists in this disease. The final report upon this material has not yet been received.

THE SO-CALLED HAMAKUA BANANA.

This banana, as has been stated, was brought to Hilo from Hamakua. The writer saw it growing in Hilo in 1904 and it was, at that time, reported to have been there some years. It has been regarded by some as identical with Bluefields, and in some cases no attempt has been made to distinguish between the two in planting. A search was made for bananas having fruits which might be known to have come directly from the Hamakua stock. Some were found which the writer was assured had grown from this stock. A careful comparison was made between these and the Bluefields. The Chinese variety was also brought into the comparison of flavor and texture. The fruits of the Hamakua lack the characteristic aroma of the Bluefields and resemble closely in flavor the Chinese variety. In form and coloring they are much like the Bluefields. The specimens in hand were larger than any Bluefields that could be found, yet this difference would not be sufficient in itself to show that the two are not identical. The conclusion was reached that the so-called Hamakua banana, while distinct from the Bluefields, resembles it so closely that the two could probably be marketed as the same variety.

The opportunity was not afforded to compare the two in relation to other characters. One of the strong features of the Bluefields banana, as grown in Central America, is its shipping quality. This is very essential in any commercial banana. Whether the Hamakua would prove a good shipper, or not, can not be stated, and for this reason, if for no other, intending planters should confine their commercial plantings to the Bluefields and the Chinese varieties, which are known to stand transportation.

THE GRAPE.

There is a small grape industry in Hawaii. Grapes are grown for home use in almost all parts of the islands at the lower elevations. In and about Honolulu and Hilo they are grown to supply the local market for fresh grapes, while in Makawao on Maui, and also in Hilo and Kona on the island of Hawaii, there is a small wine industry.

The last session of the Territorial legislature requested the station to prepare a small press bulletin on the growing of the grape in Hawaii for publication in the Portuguese language, since the industry is almost entirely in the hands of the Portuguese. Some investigation was made of the methods in vogue and the difficulties which have been met with by those engaged in the business, and a small pamphlet on the subject was issued.

THE MANGO.

NEW VARIETIES.

The work with the mango has continued along much the same lines as formerly, and, with the exception of spraying experiments, little new work has been undertaken. The working of new varieties into the orchard by budding and grafting has been continued. Some of the new varieties have been coming into bearing during the year. One of the most striking of these is the Brindabani. Perhaps the most distinctive features of this variety are its peculiar form, its heavy bearing habits, and its coming into bearing at a remarkably early age. It came into the bearing of mature fruit within 18 months from the date of grafting. The tree at 2½ years old from scion and bearing its second crop of fruit is shown in Plate IV. The fruit had been severely thinned to prevent the breaking of the tree.

MANGIFERA INDICA. Indian variety Brindabani.

History.—The original stock was received in May, 1908, from the Bureau of Plant Industry of the Department of Agriculture as an inarched pot plant. This plant was inarched upon a seedling mango tree in the orchard on December 12, 1908, produced its first crop in the summer of 1910 and its second main crop in 1911.

Description.—Form roundish oblate; size medium, averaging 8 to 9 ounces; cavity shallow, flaring, irregular; stem slender, persisting well; apex depressed; surface smooth and undulating; color green, blushed with orange and red, being a rich orange yellow when exposed to the sun and mature; dots yellow, small, very numerous, and slightly raised; bloom bluish white, quite abundant; skin moderately

thick, tough, tenacious; flesh moderately thick, orange yellow, coarse, juicy, with an abundance of fiber; seed reniform and rather thin; flavor sprightly, a trifle acid, and quite pleasant; quality fair to good. Season July to September for the main crop at Honolulu, Hawaii.

The tree is small of stature and has a broad spreading habit, lower branches often sweeping the ground. (Hunn.)

THE OAHU.

History.—A seedling tree about 6 or 7 years of age bore fruit this year, and its characteristics have given justification for naming it Oahu. It is probably a cross between the Hawaiian sweet mango and the Crescent. Although the husk is present, the seed presents an undeveloped condition with often just the seed coat present. About 75 per cent of this year's crop has had no viable seed. (Pl. V.)

The Oahu is valuable as a large, fine-appearing fruit of good quality. Its nearly seedless condition makes a thin husk with a large proportion of flesh. No mango weevil, *Cryptorhynchus mangiferæ*, has been found within these mangoes, and it will be interesting to note what may be the result of the attack of this insect on a fruit which contains no seed upon which its larva may feed. The Oahu is also worthy of propagation as a basis for breeding toward complete seedlessness.

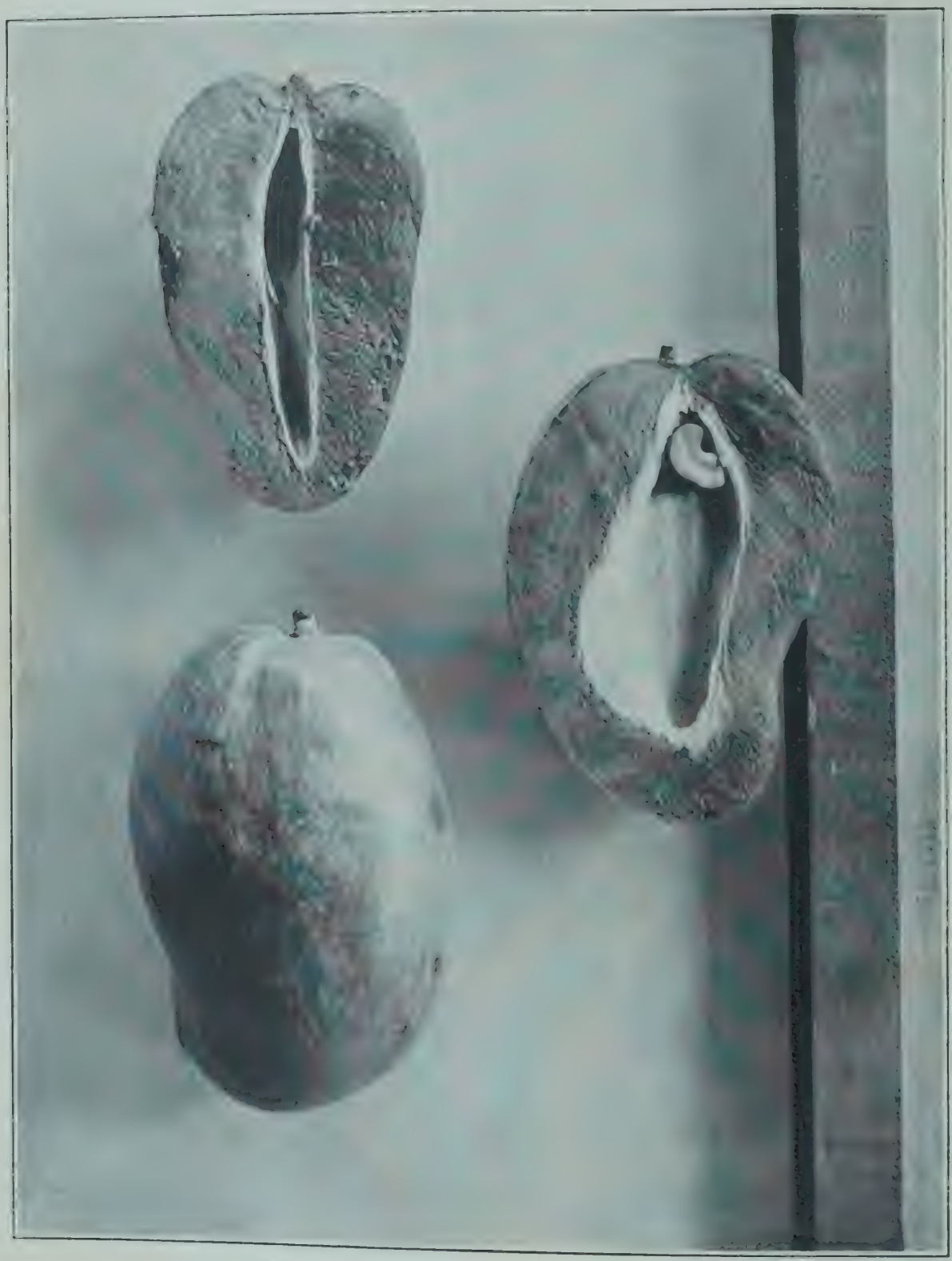
Description.—Form oblong, heavily shouldered at the cavity end and tapering toward the apical end; size large, averaging in weight from 10 to 15 ounces; cavity shallow, flaring, irregular; stem slender; apex variable, ranging from a point to a depression; surface moderately smooth and undulating; color pale yellow with a reddish blush on the exposed side; dots numerous, small, yellow, depressed; bloom bluish white, moderately abundant; skin moderately thick, tough, very tenacious; flesh thick, bright yellow, juicy, with an abundance of fiber; seed dried up or represented by just the seed coat; flavor rich, moderately sweet; quality good. Season June to August at Honolulu, Hawaii.

This tree is of the average height and presents a broad spreading habit. (Hunn.)

SPRAYING.

The mango in Hawaii is quite seriously attacked by a fungus disease sometimes called mango blight and which is due to the fungus *Glœosporium mangiferæ*. This disease causes the destruction of the flowers, the young foliage, and sometimes the young twigs. It also results in the spotting and rotting of the fruits of susceptible varieties. The same leaf-folding larva to which reference was made when

THE BRINDABANI MANGO BEARING ITS SECOND MAIN CROP OF FRUIT 2½ YEARS AFTER GRAFTING.



THE OAHU, A NEARLY SEEDLESS MANGO.

discussing the avocado also attacks the mango, its chief damage being done to the flowers and young fruits. Spraying experiments along the same lines as indicated in the case of the avocado have been carried on. It has not been found difficult in years past to control the disease with Bordeaux mixture, but because of red spider and thrips which sometimes infest the mango it was thought well to make some tests of the sulphur sprays also. The results of these spraying experiments, as well as the methods upon which they have been carried on, are given in detail, so far as they are at present available, in Bulletin No. 25 of this station, on the Avocado in Hawaii.

FRUIT MODELING.

Fruit modeling as a means of record has been used to some degree in the study of mango varieties. Modeling has some advantages over photographing or verbal description as a permanent record. The method used was applied at the station first by the late Mr. F. N. Otremba, who was an expert in this line of work. The method, however, is so simple and convenient that it does not require artistic talent to use it successfully. Other members of the staff have found it convenient, and it might be worth while here to record the method for the convenience of others who may wish to apply it.

The principle involved is simply to make a mold by pouring a medium of glue and gelatin about the fruit to be modeled. This when cold is cut open and the fruit removed, leaving the mold, into which plaster of Paris is placed in a liquid form and allowed to solidify, making the cast. The details are as follows:

The mold.—This is formed of fish glue and gelatin. The glue should be reduced to the liquid form with water by being heated in a kettle surrounded by water and placed over a slow fire. When liquefied add the gelatin. About 1 pound of gelatin to $2\frac{1}{2}$ pounds of glue has been satisfactory.

The box or container.—This may be made of wood, but we have found that for fruits of ordinary size a flower pot can be used very conveniently and saves much trouble. If made of wood, the box must be held together by wire or twine so that it can readily be taken to pieces. A flower pot has the advantage of being larger at the top than at the bottom and therefore the mold can be removed without great difficulty. The inside of this container must be well coated with shellac and each time before the mold is made must be well oiled. A mixture of 50 per cent olive oil and 50 per cent kerosene is, perhaps, most satisfactory, but cottonseed or ordinary raw linseed oil would probably serve the purpose.

Making the mold.—Oil the fruit to be modeled and place it in the container, which should be large enough to allow an inch or more on

each side of the fruit and between the fruit and the bottom. The fruit may usually be suspended from a small nail driven through a stick which rests upon the top of the pot and is tied down at the ends to the shoulder of the pot. This will prevent the fruit from rising to the surface when the glue is poured into the container. While the glue is warm, but not too hot, pour it into the container, distributing it on all sides so as not to crowd the fruit to one side. Allow it to remain so overnight. In the morning remove the mass of glue from the container. With an oily knife cut one side of the mass from end to end or as far as may be necessary. Gently release the fruit and remove it, leaving the mold empty. At the same time cut a small opening at the highest point to receive the plaster of Paris. Allow the mold to dry for half an hour and then apply to its interior, with a brush, a coating of about 10 per cent formalin to harden the surface.

Making the cast.—After the formalin has evaporated apply a coating of oil to the interior of the mold and also oil the interior of the container into which the mold must now be placed. It is sometimes necessary to tie the mold together before replacing it in the container. Take the required amount of plaster of Paris and add to it enough water to make a thick liquid. Mix this well so as to free it from all lumps and pour it into the mold through the opening made in the top. Shake the mold with a circular motion to force the plaster of Paris into all parts. Allow it to stand for an hour or more when it will be sufficiently solidified to be removed. It may then be taken out with the same care with which the fruit was removed.

Coloring the cast.—If it is desired to have a reproduction of the color of the fruit as well as the form, this may be done with water colors, but for this part of the work some familiarity with color work will be necessary. Any slight imperfections must first be removed. Sometimes minute holes, which have failed to be filled by the plaster of Paris, are to be found. These may be filled by first dipping the cast in water and then painting it with a very dilute coat of plaster of Paris. These may not be filled by one or two coatings, but care must be taken not to alter the shape of the fruit. To prevent the colors from striking into the cast it is necessary to coat the latter with a very thin glue, applied with a brush, after which the colors may be applied.

CITRUS FRUITS.

The citrus orchards have been extended somewhat during the year. A number of new varieties have been budded into the orchards and nurseries. There are now growing on the station grounds the follow-

ing varieties of citrus trees, of which quite a number budded in 1909 are in fruit at this writing:

ORANGES. (29 varieties, 126 trees.)

Bouquet des Fleurs.
Centennial.
Dancy Tangerine.
Dugat.
Du Roi.
Enterprise Seedless.
Golden Buckeye Navel.
Golden Nugget Navel.
Hart Tardiff.
Jaffa.
Joppa.
King Mandarine.
Lamb's Summer.
Magnum Bonum.
Majorca.
Maltese Blood.
Mediterranean Sweet.
Paper Rind St. Michael.
Parson Brown.
Pineapple.
Ruby Blood.
Satsuma.
Scented Orange.
Tangerine.
Thompson Improved Navel.
Valencia Late.
Variegated Navel.
Washington Navel.
Navelencia.

POMELO. (11 varieties, 59 trees.)

Duncan.
Imperial.
Whitney Imperial.
Marsh Seedless from California.
Marsh Seedless from Florida.
McCarty.
Pernambuco.
Royal.
Tresca.
Triumph.
Woodworth.

LEMON. (6 varieties, 35 trees.)

Seedless Campucinni.
Eureka.
Genoa.
Lisbon.
Ponderosa.
Villafranca.

LIME. (2 varieties, 6 trees.)

Kusaie.
Tahiti.

CITRON. (1 variety, 1 tree.)

Citron of commerce.

ACCESSIONS AND DISTRIBUTIONS.

ACCESSIONS.

Among the numerous accessions of the year a few should receive special mention. Seeds of the date palm (*Phœnix dactylifera*), said to be of unusual merit, were collected by Dr. Wilcox in Arizona

during the early part of the year. These are reputed to be of a strain which produces good fruits from seed. They have germinated well and will be soon ready for planting out.

The *Agava lespinassei* and *A. zapupe* were received from the Office of Foreign Seed and Plant Introduction, Department of Agriculture. Most of these were given into the custody of Mr. William Weinrich, manager of the Hawaiian Fiber Co.'s plantation on this island, where they will be propagated and from which source the station can secure plants for distribution if desired later. A few of the plants were retained on the station grounds.

A new variety of pigeon pea known as Cadios was received from the Philippine Islands.

Plants of *Canarium commune*, S. P. I. No. 25684, were received by mail and are recovering from the effects of this long transportation.

Greigia sphacelata, a decorative bromeliad related to the pineapple, was received from the same source as the above. The fruit of this species is said to be held in high esteem in Chile.

Several species of Anona have been received and planted.

Bud wood of a number of varieties of citrus was received from Mr. G. P. Wilder, who collected them on his tour around the world. These included a seedless lemon called the Capucinni, and bud wood was received from Kauai of a variety of orange known as the Scented Orange, which was observed by the horticulturist several years ago, and which had the finest color of any orange that he has seen growing in Hawaii.

DISTRIBUTIONS.

Quite a large number of plants have been propagated and distributed during the year. The chief purpose of this has been to introduce certain varieties of plants and disseminate them more widely in the Territory. Among these have been the Merced variety of sweet potato. This is probably the same variety as is known in the East under the name "Jersey Sweet." Reference was made in the last annual report to the possibilities for marketing this variety of sweet potato on the mainland. In order to assist in this matter, plants or roots have been distributed to all who have applied. Something over 3,000 plants have been sent out besides a number of shipments of roots.

Banana offsets have been distributed in considerable numbers. The supply of the Bluefields variety, for which there is a great demand, has become so reduced that the distribution of these has been suspended for the present. It is hoped that these will soon be sufficiently disseminated in the islands so that the station will no longer need to engage in the distribution.

About 300 seeds of *Aleurites cordata*, one of the wood oil nuts, were received from the Office of Foreign Seed and Plant Introduction, Department of Agriculture, and were distributed to several parts of the islands, where it is thought they will have the best chance to prosper. The same species has been planted at several times on the station grounds, but this locality does not seem to be well adapted to the plant.

The orchards and nurseries of the station have now grown sufficiently so that it has been possible during the past year to distribute citrus bud wood to all who have applied. This material has been of several varieties.

In connection with the papaya work reported above, about 250 packages of best selected seeds have been distributed and about 9 pounds of ordinary selected stock.

The *Carissa arduina*, a new fruit and ornamental shrub described in the report for 1910, has been distributed to the extent of over 2,000 plants and many packages of seeds.

The roselle has been sent out in about 80 packages. This plant is now rather widely disseminated and it does not seem necessary for the station to longer engage in its distribution.

Numerous requests have been received for seeds of pigeon pea and cowpea for windbreaks and cover-crop purposes, and over 200 pounds have been distributed.

HIBISCUS.

Mr. Valentine S. Holt, assistant in horticulture, donated to the station his private collection of hibiscus. A small amount of time has been devoted to the breeding of new varieties of this most ornamental plant. There are probably few, if any, plants of more promise for ornamentation in the islands than the hibiscus. The plant grows in comparatively dry and poor soil and has been planted at the station in places formerly occupied by weeds and lantana and where little else would prosper. While there may be some who will think that the hibiscus is of little economic importance it may be said that its popularity is evinced by the large demand for varieties of this genus. The first Hawaiian exhibition of hibiscus was held during the month of June, 1911, and astonished even those most familiar with these plants by the number and beauty of the varieties which were brought together. The station cooperated in this undertaking by exhibiting its flowers. Over 3,000 cuttings of different varieties have been sent out. A method has been adopted in this propagation work by which the plants can be multiplied rapidly at nominal expense. Cutting beds of ordinary beach sand have been prepared in the open. The cuttings are tied up in bunches

of 50 to 100 and planted in the sand where they root readily. They are thus rapidly put in and can be rapidly removed.

NEEDS.

The chief needs of the department of horticulture at the present time are increased facilities for propagation. On this subject, Mr. Hunn, who is in charge of the propagation work, submits the following data:

During the year I presented you a lengthy report of the condition of affairs in regard to our present situation and facilities for seed and plant propagation. A resubmission of this report with added emphasis would be in place at this time. Our facilities are inadequate to successful propagation. There is no usable means by which to obtain bottom heat so needful in propagation work. The temperature can not be regulated. Protection is almost nullified by our present appointments, while diseases, insects, and rodents must be constantly combated. The condition in the potting room remains the same, while the shade houses are deteriorating. We have had to brace some of the walls of the shade houses and have removed benches which were rotten and of no further use.

The situation has been partly relieved by the erection of six outside benches—each 18 feet long and 4 feet wide. The supports were erected in pots which are kept constantly filled with water, thus making the benches ant proof. A woven-wire box, 8 meshes to the square inch, 2½ feet high, has been built on each bench. These benches were primarily erected for the purpose of hardening off plants and to protect them against ants and rodents. Circumstances have compelled us to use them for propagation benches.

The need for better facilities for propagation has certainly become imperative. There is no glass house in the horticultural department and no means by which delicate plants can be protected from heavy rains. The shade houses, which have been very satisfactory for older and more established plants, are now in a dilapidated condition and are liable to fall down in any storm. It is hoped that some arrangement may be made for this work.

In closing it is desired to express appreciation of the very faithful services of Mr. C. J. Hunn, assistant horticulturist, and Mr. Valentine S. Holt, assistant in horticulture.

REPORT OF THE CHEMIST.

By W. P. Kelley.

The work of the chemical department during the year has been devoted to soil investigations, plant physiology, and miscellaneous analyses.

SOIL INVESTIGATIONS.

The soil investigations have been continued along the lines suggested in the previous report. The conditions in certain cultivated sections of the islands, together with the experience of farmers and members of the station staff, have convinced us of the need for an investigation of soil factors not commonly studied in agricultural investigations. The difficulties attending the continued cultivation of pineapples on Oahu and the failure to manage successfully some of these soils by the use of the usual cultural methods and fertilizers indicate that other factors demand attention. These investigations have been along two general lines, which may be classified as physical and chemical. The study of soil physics has been conducted with special reference to the movement of water in certain types.

For a considerable time it has been apparent that one of the fundamental difficulties in pineapple cultivation is faulty drainage, and it already appears that if a permanent system is to be evolved under the prevailing climatic conditions, it is necessary more thoroughly to comprehend the physical factors involved. The results thus far obtained have a direct application to the pineapple soils of Oahu. In addition it is believed that these soils offer opportunities for studies of a scientific nature, the result of which may have a much broader application. In certain of these soils physical factors play an abnormal part in their productivity, but it is also likely that in such instances there is only an exaggeration of what exists in soils throughout the islands and to some degree everywhere.

THE MANAGEMENT OF SOILS.

It is commonly held that the free circulation of soil moisture is indispensable to the normal growth of higher plants. All plants, however, are not equally sensitive to adverse physical conditions. The pineapple is a particularly sensitive plant and often fails to vegetate as a result of a number of causes. Among the easily recognizable causes of failure, the lack of sufficient drainage is one of the most

apparent. Usually cultivation and frequent tillage accelerates drainage by keeping the soil open and preventing its becoming compacted. At the same time a loose soil is more retentive of moisture in times of continued dry weather.

The frequent and thorough tillage of certain pineapple lands in the Wahiawa district is sometimes attended by a retardation of the movement of soil water during times of wet weather. The chief cause of this condition has been found to be associated with the fact that sufficient care has not been exercised in the cultivation of these soils. At various times during the year continued rains bring about saturation of the soil, at which times the growth of weeds is very rapid. The farmers feel compelled to cultivate at such times before the soil becomes properly dried out. This cultivation has resulted in puddling the soil to such an extent that natural drainage is greatly hindered.

Particular emphasis has been placed on this phase of the question in a previous publication devoted to the management of pineapple soils.[1] In addition the investigation has led to a further study of the movement of water in other soils in the islands.

CAPILLARY RISE OF MOISTURE.

If we are to understand the peculiarities of these soils and foresee what will be the results of a given treatment, it is essential to understand the fundamental movement of water in them. Ordinarily soils contain four kinds of water, namely, water of chemical combination, such as enters into the composition of clays and other hydratable substance; hygroscopic water; capillary water; and free circulating water. The first two of these will not be discussed at this time further than to point out that the chemically combined water in pineapple soils appears to be abnormally high, the explanation of which, however, is found in the physical composition. Frequently these soils contain from 30 to 50 per cent of finely divided substances, ordinarily called clay, a large part of which contains water of hydration.

Capillary water or moisture except in times of wet weather forms the nutrient solution in which the several mineral substances necessary to plant growth are dissolved. Such water comprises thin films which more or less completely envelop the soil particles, connecting them, and the movement of which is dependent upon various conditions. The force which brings about movement in this moisture is usually referred to as capillary attraction and is caused by surface tension. The capillary movement of soil moisture in other countries has been investigated to some extent. The soils throughout Hawaii, however, are unlike ordinary soils in a number of particulars. Their chemical composition is different and the physical make-up unlike

[1] Hawaii Sta. Press Bul. 29.

that of most soils. It is therefore of some scientific interest to determine the relative movements of water in these soils. In addition, such a study is of practical importance to the pineapple growers.

In this investigation soils of widely different physical structure have been used. The following table shows the relative percentages of the different-sized particles contained in the samples used:

Mechanical composition of soils.[1]

Serial number.	Loss on ignition.	Fine gravel.	Coarse sand.	Fine sand.	Silt.	Fine silt.	Clay.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
7	13.14	.....	0.77	3.64	8.85	34.54	36.28
9	16.77	0.87	8.20	22.44	13.94	23.13	13.11
15	16.66	2.54	6.28	21.17	14.57	21.90	15.50
61	25.16	.12	7.20	40.90	9.85	15.01	2.93

[1] Analyses made by the method of Hall. The Soil. London, 1908, 2. ed., p. 51.

Finely pulverized air-dried soil was prepared by rubbing samples in a mortar with a rubber pestle so as to reduce the larger aggregates without crushing the ultimate particles. Portions were then inserted into glass tubes 4 feet in length and 1 inch in internal diameter by the use of a long roll of paper, by means of which the soil was introduced into the tubes in such a way as to leave it in an unbroken column. In order to prevent the soil from falling out the lower end of the tube was closed by a piece of fine muslin stretched over it. These columns were suspended in such way as to allow the lower end to dip beneath the surface of distilled water. The upward capillary rise of moisture could be easily observed by the wetting of the soil and was measured from time to time. The following table shows the results:

The capillary rise of moisture in soils.

Time.	Heavy clay No. 7.	Silty soil No. 9.	Silty soil No. 15.	Highly organic sandy soil No. 61.
	Centimeters.	*Centimeters.*	*Centimeters.*	*Centimeters.*
10 minutes	5.5	7.5	6.5	7
20 minutes	7	9.5	9.5	9.5
30 minutes	8	11	12	11.5
45 minutes	9	12	14	13.5
1 hour	10	13.5	15.5	15.5
2 hours	11.5	16.5	20	20
3 hours	13	19.5	22.5	24
4 hours	14	21.5	24	27
5 hours	15	23.5	26.5	29.5
6 hours	16	24.5	28	31.5
1 day	22	37.5	41	48
2 days	24	41	45	57
3 days	24.5	43.5	52	63.5
4 days	25	44.5	55	66.5
5 days	26	45	57	69.5
6 days	27	45	58	74.5
7 days	27.5	48	60	77.5
8 days	27.5	48	62	79.5

These data show that the upward capillary movement of water in these soils varies between wide extremes. It was found to be greatest in sample No. 61, which is a highly organic soil from the Kula district of Maui and contains a very small percentage of clay. Next in the upward movement are soils Nos. 15 and 9, both of which are composed largely of silts and fine sand. The most retarded capillarity

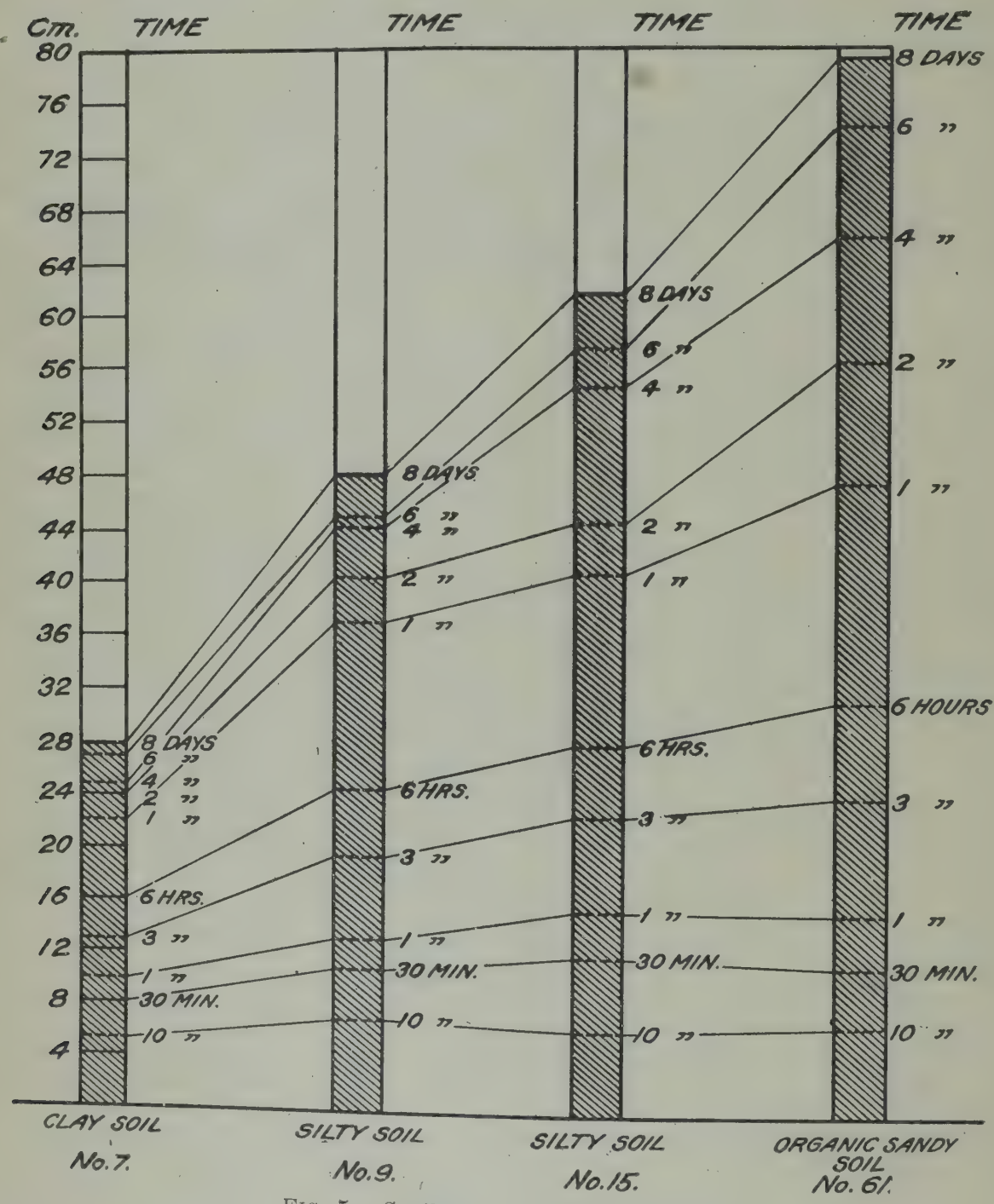


FIG. 5.—Capillarity in different soils.

was found in soil No. 7, a heavy clay. The capillarity in the different soils is diagrammatically shown in figure 5.

From this investigation it is shown that the capillarity, and hence the power to maintain a good moisture content during continued dry weather, varies in these soils between wide extremes. Clay should have a greater capillarity than coarser particles, and therefore water

ought to rise to a higher level in clay soils if other factors were not involved. Loughridge [1] has shown, however, that the rate of capillarity is proportional to the size of the particles, while the maximum height to which water will rise is greater in the silts. Clays when moist gradually become colloidal, and in consequence offer resistance to the passage of water by increasing the friction, which finally becomes sufficiently great to balance the force of capillarity. The amount of colloidal clay in soils is not always proportional to the percentage of clay found by mechanical analysis and, further, clays of different sorts become colloidal in varying degrees.

It should not be considered that the conditions in these experiments exactly duplicate those of the field, and consequently the movement of water herein reported is not the same as takes place in the field. On the other hand, however, the data are comparable and give an idea of the relative movements that take place under natural conditions. The general field observations are in accord with the experimental findings.

In addition to the upward capillary movement of soil moisture there is also what is known as downward capillarity. With a view of determining the rate at which this movement will take place, an additional set of tubes prepared as above were kept under a constant water head of 1 inch. The following table records the results:

Downward capillarity in soils.

Time.	Heavy clay No. 7.	Silty soil No. 15.	Organic sandy soil No. 61.
	Centimeters.	*Centimeters.*	*Centimeters.*
5 minutes....	8	10	9
15 minutes...	15	16	14
25 minutes...	19	20	19
45 minutes...	25	26	25
1 hour.....	29	29	32
2 hours.....	44	45	45
3 hours.....	61	60	60
4 hours.....	74	76	69
5 hours.....	80	80	76

The downward capillarity of these soils is thus shown to be essentially the same. In addition the movement under the conditions of the experiment was very much greater than was the capillary rise. These data, however, should not be interpreted to mean that the downward flow of soil water is the same in these soils. The rate at which water will flow through the soil in addition to the capillary movement of moisture forms a more adequate basis for conclusions regarding drainage. In order to determine the percolating power of these soils the same tubes used in the last set of experiments were

[1] California Sta. Rpt. 1904, p. 33.

allowed to stand until the downward movement of moisture had reached the bottom of the tubes, after which the amount of water which drained through was collected in graduated cylinders and measured.

Percolation through soils.

Time.	Heavy clay No. 7.	Silty soil No. 15.	Highly organic sandy No. 61.
	Cc.	*Cc.*	*Cc.*
1 hour	10	22	15
2 hours	11	40	30
3 hours	12	57	45
4 hours	14	70	58
5 hours	16	80	72
1 day	66	155	184
2 days	93	222	407
4 days	136	363	817
5 days	155	435	1,095
6 days	170	508	1,215
7 days	182	586	1,345
8 days	190	662	1,490
9 days	196	741	.....
10 days	210	.....	.....
11 days	218	.....	.....
12 days	226	.....	.....
13 days	235	.....	.....

These data indicate the relative rates of drainage that would be expected to take place in the field. As already stated, soil No. 7 is a heavy clay, having been taken from a field in which natural drainage is very poor. By comparing the mechanical composition and the percolation, it is seen that the soils containing the highest percentage of clay and fine silt permit the flow of water through them at the slowest rate. The air spaces in soils of high clay content are small in size, so that the capillary force, being proportional to the surface, is also great; but the resistance offered to the movement of water is, on account of friction, relatively greater in clay soils. The clay in soil No. 7 is not composed of silicate of aluminum alone but contains a very high percentage of iron, the analyses of which have shown as high as 35 per cent Fe_2O_3. A part of this iron exists as ferric hydrate, which, in addition to containing water of hydration, becomes gelatinous when wet, thus further inhibiting the free movement of water through it. Also we have evidences of the existence of a double silicate of iron and aluminum, which compound is colloidal and very finely divided and appears to have a tendency to reduce the flow of water through the soil even more than ordinary clay.

The accompanying diagram (fig. 6) shows the rate of percolation through different soils.

The samples used in the previous experiments were thoroughly air dried at the outset and it was observed that the percolation was greater at the beginning than toward the end of the experiment. This may be taken as evidence of the gradual hydration of colloids, which by somewhat swelling tend to hinder the free passage of water.

From the data it appears that drainage would gradually become slower during a long-continued wet season, especially in soils similar to No. 7. In the more porous soils, however, such effects would not be observed. The subsoil underlying No. 7 also contains a very high percentage of clay, which makes natural drainage more difficult. In addition the organic matter of this soil is low.

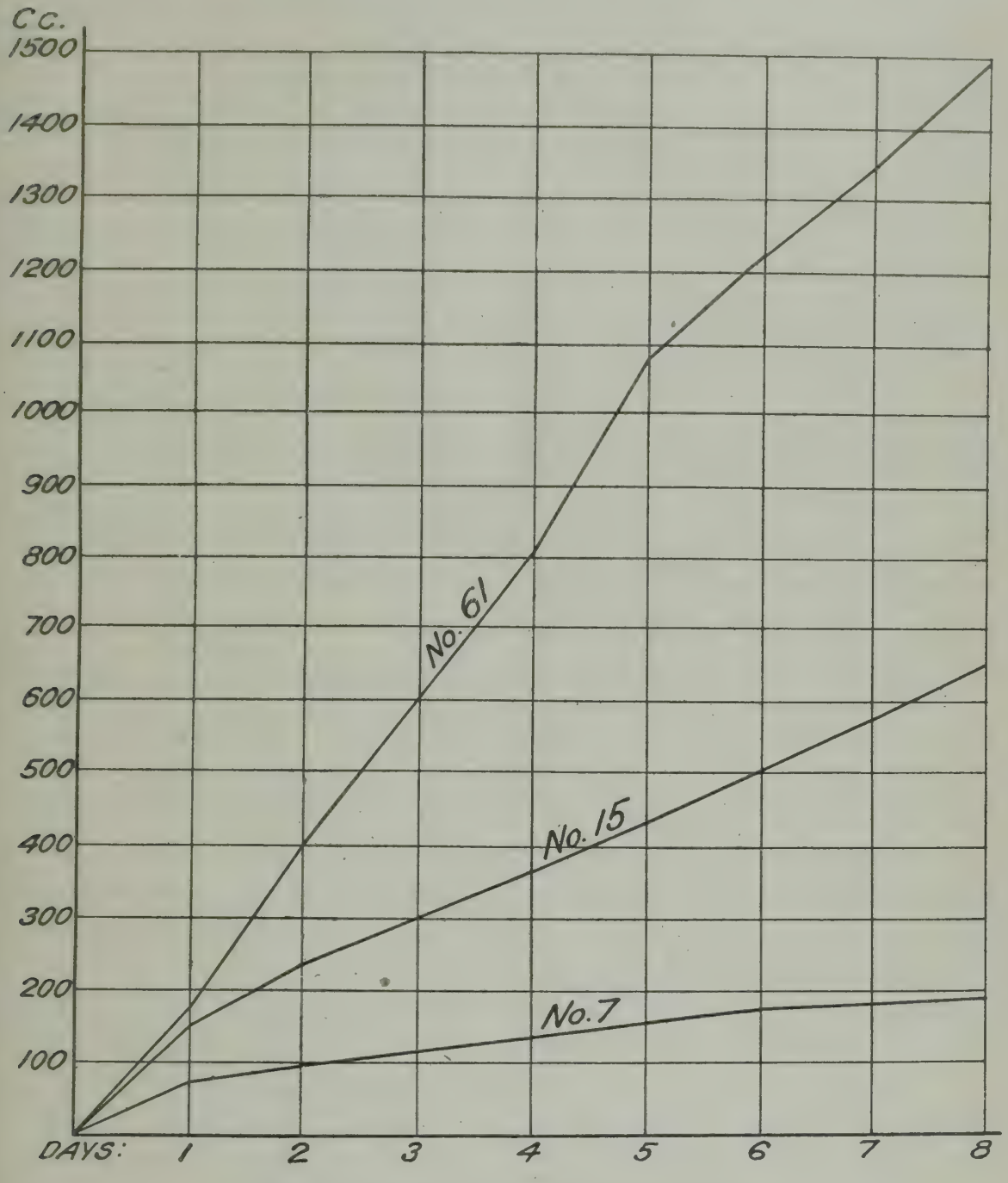


FIG. 6.—Percolation through different soils.

The management of soils similar to No. 7 requires the greatest of care if good tilth be maintained. Under no circumstances should they be tilled when wet and, in addition, crops should be rotated and organic manures and green manuring crops used as often as possible. By increasing the organic matter of such soils, a granulation of the clay can be gradually effected and at the same time greater porosity and better natural drainage will result.

SOIL ORGANIC MATTER.

An extensive study of the several methods previously used in the determination of the so-called humus in soils has been made by Mr. W. T. McGeorge, assistant chemist, and the results of this investigation are now being prepared for publication. In this paper it will be shown that none of the methods usually employed in this determination can be relied on with Hawaiian soils. A modification of the Cameron-Brazeale method, however, has been found to be both accurate and practical. Hawaiian soils contain abnormally large percentages of an extremely finely divided ferruginous clay which will remain in suspension in an ammoniacal extract indefinitely and can not readily be removed by ordinary filtration, sedimentation, or coagulation. The use of a clay filter, modified so as to prevent the absorption of organic matter and at the same time overcome any dialyzing effect, has been found to be effective and practical. In this connection some attention has been given to a study of the organic matter of Hawaiian soils, and sufficient data have already been obtained to warrant the conclusion that the organic matter of these soils is made up of extremely complex mixtures, varying from soil to soil, and perhaps different in some degree from the organic matter of soils of older formations.

SOIL SURVEY.

Samples of soil from the various sections of the islands are being collected from time to time, and chemical and physical analyses are being made as fast as opportunity permits. This work will be continued until the soils from all the important upland districts have been systematically examined. Previous classifications of the island soils have been of a very general nature, and, with the exception of the sugar lands, no systematic effort has been made toward the classification and grouping of the soils. With the advance of diversified agriculture into the previously unoccupied lands, information concerning the composition and properties of these soils becomes of greater importance. A classification and survey of these soils in the sense it is understood in older countries may never be possible, but a general survey and location of local types and the study of their properties will undoubtedly be of great use to future agriculturists.

In this work new and rare types have already been discovered. In addition to the highly manganiferous soils of Oahu, the occurrence of an extensive body of highly titaniferous soil has recently been found. Samples have been analyzed which, in some instances, contain 20 per cent titanium, expressed TiO_2. This soil has peculiar properties which are of both practical and scientific interest. Other

sporadic soils having abnormal properties have also been found. Sufficient data have already been accumulated, therefore, to justify the conclusion that the upland soils of the several islands present a range of variation in composition and properties by no means common on such limited areas.

FERTILIZER EXPERIMENTS WITH COTTON.

In cooperation with the agronomist, fertilizer experiments with cotton have been conducted for the past two years. The results obtained are fairly concordant and will perhaps be of some interest to the cotton growers of the islands. These experiments were conducted on the lands of the Kunia Development Co. and the upper portion of the Oahu Sugar Co.'s land, both on Oahu, and in each instance dry-land culture was employed without the use of artificial irrigation. The small yields are in part due to the lack of sufficient moisture, and the effects of the several fertilizers, while relatively striking, would no doubt have been greater under more moist conditions. Fertilizers to be of the greatest benefit require an abundance of moisture in the soil. In some instances the application of fertilizer to pineapples at the beginning of a dry season produced little effect, and examination some weeks later showed the fertilizer to be apparently unchanged in the soil. In other instances near by a similar application, when followed by sufficient rains, brought about excellent growth. The Seabrook strain of Sea Island was used in these experiments with the following results:

Yields of seed cotton in fertilizer experiments.

Fertilization.[1]	Size of plat.	Kunia.		Waipahu.			
		1909		1909		1910	
		Yield per acre.	Increase per acre.	Yield per acre.	Increase per acre.	Yield per acre.	Increase per acre.
	Acre.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Check	3/40	240	.....	119	.....	147	.....
Superphosphate, sulphate of potash	3/40	347	16	218	88	220	105
Dried blood, superphosphate	3/40	416	85	217	87	267	152
Dried blood, sulphate of potash	3/40	307	.....	66	.....	103	.....
Check	3/40	320	.....	66	.....	83	.....
Dried blood, superphosphate, sulphate of potash	3/40	470	139	278	148	257	142
Ammonium sulphate, superphosphate, sulphate of potash	3/40	480	149	440	310	190	75
Nitrate of soda, superphosphate, sulphate of potash	3/40	450	119	572	442	313	198
Check	3/40	353	.....	161	.....	100	.....
Dried blood, basic slag, sulphate of potash	3/40	453	122	356	226	263	148
Dried blood, dicalcic phosphate, sulphate of potash	3/40	490	159	546	416	352	237
Dried blood, superphosphate, sulphate of potash, lime	3/80	587	256	665	535	353	238
Lime	3/80	427	96	197	67	133	18
Check	1/10	412	.....	174	.....	132	.....

[1] The fertilizers were applied so as to provide the following quantities per acre: Nitrogen, 20 pounds, phosphoric acid, 50 pounds, and potash, 30 pounds.

From these data it is clear that phosphates are the most needed fertilizing material in these soils and that there is some difference in their relative values. Dicalcic phosphate appears to have been somewhat more effective than other forms. These soils contain considerable phosphoric acid, but it is very largely combined with iron and alumina in extremely insoluble combinations.[1] It is likely that an easily soluble phosphate, like superphosphate, would tend to combine with the iron and alumina of these soils, forming difficultly soluble compounds, to a greater degree than the less soluble dicalcic phosphate. Potash and nitrogen, unless applied in conjunction with phosphates, produce little effect, and on the Waipahu experiment nitrate of soda was more effective than other forms of nitrogen. Lime likewise was ineffective when applied alone. The greatest yields in each instance were obtained by the combination of lime and a complete fertilizer. The experiment at Waipahu in 1910 was a continuation of that in 1909, the same plats being used in the two years, and the cotton was grown as a perennial. The fertilizer at the beginning of each of these experiments was applied in the furrows before planting. In 1910 the fertilizer was applied in February around the old plants and thoroughly worked into the soil. The total yields do not fully explain the noticeable effects from the treatment, for the plats treated with phosphates came into picking earlier than the others and yielded a greater percentage of their total harvest in fewer pickings than the unfertilized plats. Credit is due and thanks are here extended to Mr. F. G. Krauss and Mr. C. A. Sahr for cooperation in these experiments. The success of the trials was made possible largely as a result of their cooperation.

RICE INVESTIGATIONS.

The fertilizer experiments with rice have been continued as in previous years and with similar results. In these experiments two crops of rice have been grown on the same land each year, and where ammonium sulphate was applied to each crop before planting the yields have been fully maintained. By the application of fertilizer to the spring crop only, however, the yields are gradually becoming smaller. The plats to which no fertilizer has been applied have become so reduced in crop-reducing power that an unprofitable yield is now being obtained.

The experiments with different forms of nitrogen have been concluded and the results published.[2] In these experiments it was shown that ammonium sulphate is a suitable fertilizer for rice, but nitrate of soda is ineffective. By the use of pot experiments it was deter-

[1] Jour. Indus. and Engin. Chem., 2 (1910), p. 277.
[2] Hawaii Sta. Bul. 24.

mined that rice absorbs nitrogen largely from the ammonium form and that if nitrates constitute the only form of combined nitrogen accessible to rice poor growth and unhealthy plants result. Rice appears not to have the power properly to transform nitrates into proteids.

INFLUENCE OF MANGANESE ON PLANTS.

The investigation on some of the functions of manganese in plant growth have been continued throughout the year, and the results are being prepared for publication in a bulletin on this subject. In this investigation it has been found that manganese affects the mineral balance in practically all plants examined, and causes the plants to take up an abnormal amount of lime and smaller amounts of phosphoric acid and magnesia than are absorbed normally. Not all plants are equally sensitive to manganese, and a number of species show no visible effects from it. Further discussion of this question is reserved for the subsequent publication.

REPORT OF THE AGRONOMIST.

By C. K. McClelland.

In the agronomy division experiments with rice and with cotton have continued to be the principal work undertaken, while those with alfalfa, soy beans, peanuts, and other legumes, also with corn and sorghum, have been of secondary importance. During the year the retiring agronomist prepared a bulletin upon Leguminous Crops for Hawaii, and also a press bulletin upon Peanuts in Hawaii.[1]

RICE EXPERIMENTS.

The work continues with rice because of its importance in Hawaii, and with a hope that in the near future locally grown rice may regain the former importance in home consumption which it seems to have lost. Attention is called to the fact that rice is the only subsistence product raised in large amounts which is consumed by the "foreign" class of people, which class greatly outnumbers the native or taro-consuming class. So that if at some future time imports into the islands should for any reason be cut off, the rice crop would be the means of preservation of the foreign population, which without rice would, so to speak, be threatened with starvation. As noted in previous reports, the conditions surrounding the rice industry are very peculiar, in that, though the Chinese are the principal growers of rice, the Japanese are by far the largest consumers, and as they prefer Japan rice the imports of rice from Japan increase yearly.

The reasons given for this in the 1908 report were lack of flavor, strength, richness, or fattiness in the Hawaiian-grown rices, even in Japan varieties produced here. Chemical analyses made by the Bureau of Chemistry of the United States Department of Agriculture show that what little difference there is in composition is in favor of the Hawaiian rices. Another reason given the writer is to the effect that upon cooling the Hawaiian rices fall apart and become dry and rubbery, while the Japan rice, which in cooking also retains its individuality of kernel, upon cooling is held together and does not become dry and rubbery. Furthermore, the Japanese, being a very loyal people, prefer to spend their money in helping their countrymen who are the growers, importers, and transporters of this rice.

[1] Hawaii Sta. Bul. 23 and Press Bul. 29.

Whatever may be the reason, the actual facts are that Japan rice is consumed by the Japanese and in smaller amounts by the whites; while the Hawaiian Gold Seed or Chinese varieties are consumed by the Chinese and whites or shipped to California for the Chinese there.

In order to procure, if possible, a rice that would satisfy the taste of the Japanese consumers, the former agronomist visited Japan and brought back several of their better varieties which have now been grown at the station through three generations. The following table shows a comparison in yields between these and a former importation which has been grown here for several years but which seems to have deteriorated in quality:

Yield of Japanese varieties of rice grown at the station.[1]

Varieties.	Spring, 1910.	Fall, 1910.		Spring, 1911.
		Fertilized.	Unfertilized.	
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
Benkei	4.00	20.00	18.00	63.25
Miyako	3.75	19.00	18.25	74.75
Omachi	4.87	18.00	20.00	95.25
Shinriki	4.23	24.00	20.50	82.50
No. 153 (old variety)	4.15	14.25	11.75	100.00

[1] The areas were different for different seasons, but the same for all varieties for each season.

Of these rices the Miyako is the only one which has been produced in sufficient quantity for a culinary test. A resident of Honolulu who lived for many years in Japan reports this rice, as grown in Hawaii, "to cook as well as the imported Japanese rice, and, also, when cold, it keeps its moisture, which the Hawaiian does not do. It has not the oily strength of the native Japanese rice, but in taste and appearance quite equals, I think, the native rice of Japan." By another year it is hoped to have had all of these varieties tried out and thoroughly tested by the Japanese themselves.

In the spring crop of 1911 two variations were noticed from the growth of these rices: The Benkei variety developed a heavy tillering habit, which the Shinriki seems to have lost; and the Omachi, which is a bearded rice, was almost entirely beardless. If the latter rice will not deteriorate in quality under Hawaiian conditions it will no doubt be the rice to grow in these islands. Small lots of seed of all these rices were given to several growers, but it is difficult to get any of them to undertake any experiment with small lots of seed.

For the fall crop of 1911 a considerable quantity of the Omachi and of the Shinriki have been put out for trial, and a test of these can soon be made. The old variety, No. 153, was a selection from an importation made from Japan by a Chinese rice grower. This rice, as before stated, seems to have deteriorated in quality in the several

years during which it had been grown in Hawaii, and because of this and partly for other reasons enumerated above, it has sometimes been sold at a loss to the producer, which fact has discouraged the Chinese growers, until it is very difficult indeed to get them to test any other Japanese variety, fearing a like result.

Ten varieties of Formosan rices were received for trial and were given their first test in the spring of 1911.

An experiment in planting 1, 2, 3, 4, and 5 seedlings in a clump resulted in nothing definite, as a different number proved the best in each different variety tried.

The fertilizer and rotation experiments with rice are being continued in the same manner as mentioned in the previous report.

COTTON EXPERIMENTS.

Because of the awakened interest in cotton the station has continued experiments with this crop along the lines mentioned in the previous report. The work with the Sea Island and Caravonica varieties has been of the greater importance, although that with other varieties has been no less interesting. It would seem from the experience with the cotton crop that the thing, more than all others combined, which will determine whether or not cotton is to be a profitable crop in Hawaii is success in controlling insect pests. Cutworms eat off the young seedlings, aphids cover and by their voracious attack stunt the young plants; then when in bloom the mealy bug, the cotton bollworm, and the leaf roller become serious pests.

COOPERATIVE EXPERIMENTS.

The cooperative experiment at Waipahu was planned as a fertilizer test in 1910, but some of the results showing a comparison of varieties may be given here:

Comparative yields of cotton.

Varieties.	Area.	Yield of seed cotton.	Yield of lint.	Percentage of lint to seed cotton.
	Acres.	*Pounds.*	*Pounds.*	*Per cent.*
Sea Island	1	202.66	54.66	27
Caravonica	1	66.12	25.37	38.37
Egyptian	1	343.75	115	33.4
Chinese upland	1	546	180.83	31.1

It will be noticed that all of the yields are rather low. The upland, as one would expect, shows the greatest yield, and the Sea Island, which one would look for in the lowest place, outyielded the Caravonica. By referring to the previous annual report it is found that the Caravonica gave the lowest yield in the first year of these tests and also in a similar one at Kunia.

The location seems to have been unfavorable for cotton, as there was only about 40 per cent of a stand reported, and of that the bollworm is said to have taken 30 per cent. It was noticed that the damage was considerably less upon the upland than upon the other varieties. In another experiment with Caravonica transplanted seedlings gave much better results than those not transplanted.

EXPERIMENTS WITH CARAVONICA COTTON.

About an acre of land at an elevation of 250 feet was planted February 4 and 5, bloomed by July 1, and was picked in six and eight pickings between October 1 and December 24, the bollworm infestation varying from 5 per cent in the third to 15 per cent in the sixth picking. The results were as follows:

Yield of Caravonica cotton.

Number of plants.	Yield of seed cotton.	Number of bolls per pound.	Yield of lint.	Percentage of lint to seed.	Length in 16ths inch.
	Pounds.		*Pounds.*	*Per cent.*	
628	424.12	90	153.25	30 to 37	21 to 30
1	[1] 0.67	60	0.244	[1] 36	[1] 24
[2] 680	469.8	.....	165.9	.....	.....

[1] Average. [2] One acre planted 8 by 8 feet.

These results, as calculated to a full acre, show quite an improvement over those at Waipahu, although only in the first year, when Caravonica is noted for its shy bearing. The length and the percentage of lint are very good, while an average of only 90 bolls to the pound of seed cotton is unusually low. This cotton was grown on the station grounds in a place quite well protected from the wind, which indicates that much better returns are to be expected when this variety is planted in protected places.

PRUNING OF CARAVONICA COTTON.

From December 5 to 8, after the sixth picking, 312 of these plants were cut back very severely; some high pruned at about 4 feet and others low pruned at about 2 feet. From the pruned branches the cotton was picked as it matured. Strength tests of fibers thus matured and picked show a gradual weakening of the fiber; i. e., the more immature the fiber or boll at pruning time the weaker the fiber in comparison with fibers matured upon the plant in the natural way.

The balance of the field was pruned back the first week in March of the present year to test the effect of different dates of pruning. The December pruning made a vigorous growth in the spring and pinching was done upon both the high and low pruned trees (leaving

some as checks in both instances), some at squaring time, and upon others not until the flowering stage. A pruning test of the Caravonica cotton and an extensive cooperative experiment have been attempted upon the plan and theory given below.

Seedlings are to be pruned when about knee high—this checks the leading stem and induces branching. The first branches are usually vegetative branches and from these grow out the fruiting branches proper.

To induce these and also to check the vegetative branches the latter are pruned when it is thought that sufficient growth has been made. Other fruiting branches spring from the first ones, and an occasional pinching back is thought to favor the production of fruiting wood and thus of squares, and at the same time to restrain the tree-forming tendency. (See Pl. VI, figs. 1 and 2.) The results of this pruning were well demonstrated in the field of Caravonica, where the shape of the trees has been determined and the size largely controlled by this method, while squares were formed earlier and in greater abundance. However, the attacks of the bollworm have been so great that a comparison of the final results will not be conclusive. As a result of their work it is safe to say scores of squares, blooms, or small bolls have been shed, and many of those that escaped at first ripened prematurely as the result of a later attack.

There seemed to be two distinct squaring periods in these plants during the spring months, with an interval of perhaps 35 days between. At the first picking, made about June 1, the percentage of bolls infested by bollworms averaged 68 per cent. It was thought that by giving the plants an annual cutting back, as described above, the bollworm could be held in check, and the infestation soon fell to about 20 per cent.

Later information upon this point is to the effect that the idea of controlling the bollworm by an annual pruning is in the main correct, but the partial failure this year to accomplish the desired result is due to the fact that the prunings were made at different times, thus allowing a breeding place for the worm, first at one side of the field and then at the other. To make the work effective the pruning should be done over a large area at the same time and the prunings burned at once to destroy the larval and pupal stages of the insect. Any larval or mature form that is left will find no bolls or blossoms in which to feed and will consequently perish.

At Makaweli, upon Kauai, the 1910 crop was mostly destroyed by the worm, following two prunings in the field at different times, while the 1911 crop, which followed one complete pruning and burning, promises to be almost entirely free from bollworm.

Upon the windward side of Oahu also there are three plantings upon a considerable scale which were given this thorough pruning

FIG. 1.—PRUNED CARAVONICA COTTON.

FIG. 2.—UNPRUNED CARAVONICA COTTON.

COMPARISON OF PRUNED AND UNPRUNED CARAVONICA COTTON.

and burning at one time, and all of these are now comparatively free from the insect.

MISCELLANEOUS EXPERIMENTS WITH CARAVONICA COTTON.

To reduce the damaging effects of the bollworm it has been found that the use of a trap, consisting of a lantern elevated above a pan of water and kerosene in the field at night, has been of material benefit, catching as many as 50 moths per night, the greater catch being made upon the stiller nights. By the use of the lantern and by cutting off and burning the infested bolls regularly the percentage of infestation in the field was reduced from 68 per cent in the first picking to 50 per cent in the second and to 26 per cent in the third picking.

Some selections were made from the field mentioned above and the yields from the individual plants were as follows:

Yield of Caravonica cotton plants.

Plant No.	Number of bolls.	Yield of seed cotton.	Yield of lint.	Percentage of lint to seed.	Length in 16ths inch.
		Pounds.	*Pound.*	*Per cent.*	
0	281	1.92	0.63	32.9	24
1	65	.9	.33	37.1	21
2	149	1.42	.48	33.5	25
3	211	1.64	.57	34.7	26
4	203	1.87	.68	36.3	22
5	449	3.26	.98	30.0	30
6	331	2.79	.99	35.6	24

A study of this table shows great variation in yield, in percentage of lint, and in length of staple. However, each plant showed a marked superiority over the average run of plants in the field. Selection "0" shows a trace of Egyptian blood and selection "5" a trace of Sea Island, indicating the mixed parentage and great variability of Caravonica cotton.

As showing the possibilities of Caravonica, the following results will be of interest:

Yield of individual Caravonica cotton plants.

Row.	Plant No.	Number of bolls.	Yield of seed cotton.	Yield of lint.	Percentage of lint to seed.	Number of bolls per pound.
			Pounds.	*Pounds.*	*Per cent.*	
26	1	569	6.56	2.73	41.6	87
26	2	446	4.23	1.72	40.6	105
26	3	300	2.73	1.12	41.2	110
28	1	602	5.61	2.28	40.6	107
28	2	323	3.04	1.28	42.1	106
28	3	189	1.65	.67	40.6	114

The results are from 2-year-old trees grown but a few feet above sea level, the plants having the number "1" in each case, of course, being outside plants and located also upon the leeward side. (See Plate VII, fig. 1.)

EXPERIMENTS WITH SEA ISLAND COTTON.

A small planting of 50 plants of this cotton was made upon the station grounds on February 10, 1910. These plants were in bloom by June 1 and the crop was picked in four pickings made on August 24, September 15, October 4, and October 31. The heaviest picking was made on October 4. The results were as follows:

Yield of Sea Island cotton.

Number of plants.	Number of bolls.	Yield of seed cotton.	Number of bolls per pound.	Yield of lint.	Percentage of lint to seed cotton.	Length in 16ths inch.
		Pounds.		*Pounds.*	*Per cent.*	
49	8,633	52.5	164	11.12	[1] 21.2	26–31
1	[1] 176	1.07	.....	.227	16–33	[1] 30
[2] 1,742	.....	1,864	.....	395	.....	.....

[1] Average. [2] One acre planted 5 by 5 feet.

One plant was taken out during the season, so that the record shows for only 49. If this is a fair example of what may be expected of Sea Island cotton there are doubtless other crops now grown in the Territory that are less profitable. The loss due to insects was estimated at about 20 per cent, which would reduce the yield by that much.

EXPERIMENTS IN PRUNING SEA ISLAND COTTON.

The last day in December these plants were pruned back to mere stumps, some being pruned high and some low. New growth started out in all cases from near the ground, signifying that when growing Sea Island as a perennial the plants should all be low pruned. From the start the plants have grown well and fully occupied the space allowed them. It may be that when grown as a perennial it will be necessary to plant it 8 by 5 feet rather than 5 by 5 feet to allow sufficient room between the rows for ease in cultivation and picking. The plants bloomed profusely in the spring and promised an early summer crop, much of which, however, was shed, owing primarily to the attacks of the bollworm. Several of the plants also were attacked by mealy bugs so severely that it became necessary to destroy them.

FIG. 1.—CARAVONICA COTTON YIELDING 2.6 POUNDS OF LINT PER PLANT.

FIG. 2.—RUST-RESISTING SORGHUM AND AMBER SORGHUM.

No additional pruning was given the plants except that a few were pinched back just preceding squaring time, the effect of which was to cause the plants to bloom more profusely and a few days earlier than those not pinched. The first picking in 1911 was made June 15 and the percentage of infestation was very great, showing the prevalence of the bollworm at this time.

MISCELLANEOUS EXPERIMENTS WITH SEA ISLAND COTTON.

From these plants a number of selections were made and the seed from these used in planting a new field of 1 acre upon the slope of Punchbowl. Before the first planting was finished it was washed out by heavy rains, and the second was made March 14 and 15, the hills being placed 5 by 5, as in 1910. Because of the damage to young seedlings from cutworms, a small amount of poisoned bran was spread about the hills in a small circle, which method has proved to be effective. Several seeds were planted in each hill in order to insure a stand and the poorest were weeded out at a later date. This field has shown great uniformity in growth from the start, and, although badly damaged by a windstorm on June 8, promises some good results by the end of the year. The presence of bollworm was noted in the field when in early bloom. A heavy spraying of arsenate of lead was made over a dozen rows to determine what effect, if any, this would have in checking the work of the bollworm.

Aside from the station plantings there have been a few small patches of Sea Island put in in various parts of the Territory. The only plantings of any considerable extent are at various places in Kona, Hawaii. In this district there is a Japanese cotton growers' association whose members have planted, or are planting, an area of about 500 acres. The climate and general conditions for the growth of cotton here are said to be better than at any other point, or in any other district in the Territory.

COTTON FIBER TESTS.

The tests of Caravonica cotton fiber from pruned branches were mentioned above. It might be added here that these fibers were of smaller diameter, but of equal length with those matured upon the plant, and the breaking strength dropped from 8.99 grams to 6.24 grams. Some Mexican cotton grown at Kunia had an average strength of 8.54 grams, but the United States Department of Agriculture reports it as being less uniform than any cotton ever tested there.

Some samples of Caravonica cotton submitted from Kunia showed, from ginned cotton an average strength of 9.3 grams, while the unginned showed 11.3 grams, which at the time this was reported was the highest strength test on record.

Sea Island cotton from the same source but which was picked from some plants that had been pulled (and consequently had immature fiber) was submitted to the Clark Thread Co., which reported rather unfavorably upon it, saying it contained a large quantity of immature fiber and nep, excessive waste, and the yarn produced was too weak for thread. Former reports of Sea Island cotton were more favorable and no doubt, as stated, this failure to make good was due to the immature fiber.

When it is considered that the average strength of Big Boll American upland is about 7 grams and of long staple varieties between 4 and 5, the value of Caravonica cotton from Hawaii is readily seen, and the need for every encouragement which can be given for its production is quickly understood.

MISCELLANEOUS CROPS.

In Hawaii the areas suitable for cultivation in the staple crops, like cane, rice, and pineapples, are fairly well defined, and the problem is to find a profitable crop for the remainder of our lands.

With this end in view, experiments were made to determine the profitableness and the limitations of cotton. Because of the use of large quantities of soy beans in the manufacture of "soy sauce" it would seem that soy beans would be a profitable crop and should be grown here rather than imported from Japan. The experiments with peanuts show that they thrive and do well here, and it may be that a peanut industry upon a large scale would be a profitable undertaking, and especially so if a number of growers in the same community could grow a sufficient area to make the erection of an oil or peanut-butter factory of some object to capitalists. One man who is experimenting with cotton has planted a quantity of peanuts in rows between the rows of cotton, insuring himself, as it were, against loss by a possible failure of the cotton. He and some others report also the growing of watermelons in like manner and at good profit.

As some interest is being shown about Honolulu in the broom industry, the station is carrying on some work with broom corn. In 1910 several rows were grown. The results calculated to acre yields show 95.4 pounds of brush from the lowest yielding row, and 501.6 from the highest. These results are rather low, as yields as high as 1,000 pounds per acre are reported from different places in the States, although, of course, average yields are not far above 500 pounds. Three plantings of corn were made again in 1911 in order to continue the test and get more complete results. This industry will probably be limited to the supplying of the local demand.

Apparently another opportunity for success upon a limited scale is the growing of sorghum and making of sorghum sirup for the

Hawaiian trade. At present the only sirup upon the Honolulu market is a corn product with "cane flavor." The sweet sorghums do well here, although attacked in the later period of their growth by rust. Quite heavy yields can be obtained, and as several ratoon crops can be grown during the year and from one seedling, 1 acre of sorghum ought to produce 1,200 to 1,500 gallons of sirup annually. Tests made upon the fourth ratoon crop this spring with only a partial extraction of the juice gave 31 per cent of juice from the stripped cane, and from this was extracted 12.1 per cent cane sugar and 2.6 per cent of invert sugar. These figures compare very favorably with those given by experiment stations in the South. This crop was grown in 90 days from the previous cutting. In view of the fact that but very little experience is necessary to learn to make the sirup; that very little outlay is required for equipment with which to make it; that no risk is run, since the leaves, tops, or grain, and the pressed canes can all be used for feeding, thus paying for the expense of raising the crop, it would seem that many Hawaiian farmers might undertake sorghum sirup making with advantage.

In connection with the above-mentioned production of forage the station has tested a number of varieties of sorghums, both saccharin and nonsaccharin. A number of these were of African origin, and from among these one was found that greatly exceeded the others in yield, while at the same time it proved to be nearly or quite rust proof. (See Plate VII, fig. 2.) The station hopes soon to distribute seed of this and thus introduce a valuable addition to our forage plants.

Soy beans, jack beans, cowpeas, velvet beans, and alfalfa were discussed in Bulletin No. 23, and require no further report here.

Another new legume, Guar, has been received from the Department of Agriculture at Washington, and its growth is very promising. Planted in rows 5 feet apart and from 2 to 6 inches in the rows one variety gave $1\frac{1}{4}$ tons to $2\frac{3}{4}$ tons per acre of air-dried forage and from 1,190 to 2,610 pounds of seed. Another variety gave yields of both seed and forage with extremes within the limits shown by this variety.

The 1910 corn trials, which included Black, Yellow Flint, Reid Yellow Dent, Boone County White, and Ensilage Pamunkey, showed the last variety and the Yellow Flint to be the better under Hawaiian conditions. In the spring of 1911 Yellow Flint and two varieties from Bolivia, Cusco and Black, were planted at the trial grounds, but were destroyed by insects. A larger planting of Yellow Creole received from New Orleans was made at a later date at the station, and at the present writing is very promising.

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HAWAII AGRICULTURAL EXPERIMENT STATION,

E. V. WILCOX, Special Agent in Charge.

ANNUAL REPORT

OF THE

HAWAII AGRICULTURAL EXPERIMENT STATION

FOR

1912.

UNDER THE SUPERVISION OF

OFFICE OF EXPERIMENT STATIONS,

U. S. DEPARTMENT OF AGRICULTURE.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1913.

HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU.

[Under the supervision of A. C. TRUE, Director of the Office of Experiment Stations, United States Department of Agriculture.]

WALTER H. EVANS, *Chief of Division of Insular Stations, Office of Experiment Stations.*

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J. DE C. JERVES, *Superintendent Homestead Substation.*
J. K. CLARK, *Superintendent Waipio Substation.*

LETTER OF TRANSMITTAL.

HAWAII AGRICULTURAL EXPERIMENT STATION,
Honolulu, Hawaii, July 15, 1912.

SIR: I have the honor to transmit herewith and to recommend for publication the Annual Report of the Hawaii Agricultural Experiment Station for the fiscal year ended June 30, 1912.

Respectfully,

E. V. WILCOX,
Special Agent in Charge.

Dr. A. C. TRUE,
Director Office of Experiment Stations,
U. S. Department of Agriculture, Washington, D. C.

Publication recommended.
A. C. TRUE, *Director.*

Publication authorized.
JAMES WILSON,
Secretary of Agriculture.

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ANNUAL REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION FOR 1912.

SUMMARY OF INVESTIGATIONS.

By E. V. Wilcox, *Special Agent in Charge.*

BUILDINGS AND GROUNDS.

As the work of the different members of the station staff continues, new conveniences are required in the station buildings for special purposes. Many interior changes have been made to better meet the new requirements. In addition to interior alterations most of the buildings have been repainted and otherwise repaired in order to protect them more fully against injurious effects of the weather, which are particularly noticeable under tropical conditions. A glass house has been erected for propagating purposes, and the old one, which had become quite unsuited to our purposes, was torn down and partly used in the construction of the new glass house. This structure is made proof against ants by means of cement pillars standing in water. Arrangements for bottom heat in the main propagating bed have been made by means of circulating water which is heated by sunlight in an outside tank. An additional workhouse has been erected for the use of the horticultural department. This contains rooms for seeds, fruit, storage of spraying machinery, and for general inside work purposes.

The trial grounds, which have been used for rice experiments and certain other field tests for several years, could no longer be leased by the station, and in order to continue experiments with rice and with certain other crops, such as cotton, taro, and soy beans, another similar area of about 2 acres near Nuuanu Avenue will be leased for use during the next few years or as long as such experiments seem necessary. With the extension of the cultivated areas on the various substations it has been found possible to carry on such field experiments as were necessary under better conditions than could be obtained on the irregular and sloping soils of the experiment station grounds. Comparatively small areas, therefore, on the main station grounds have been put under cultivation in addition to those which had been so used in previous years. A few acres of shallow soil under-

lain with partly cemented cinder-rock were planted to pigeon peas and jack beans for the purpose of increasing the supply of seed of these crops to be distributed. The yield was fairly good, although the year has been excessively dry and no irrigation was possible on this particular area. On the 2 acres of ground on Magazine Hill belonging to the experiment station no attempt has been made to introduce a water supply by pipes or otherwise, since it has been decided to use this land only in testing drought-resistant qualities of certain grasses, forage plants, and cottons. The test during the present year has been unusually severe on account of the great length of the season of drought.

CHANGES IN THE STAFF.

During a portion of the year Mr. W. P. Kelley and Miss Alice R. Thompson were absent on furlough, carrying on special studies at the University of California and Columbia University, respectively. Mr. F. A. Clowes was appointed in charge of the Hawaii substations, Mr. W. A. Anderson, in charge of the rubber substation at Nahiku, Maui, Mr. J. de C. Jerves, in charge of the Homestead substation on Kauai, and J. K. Clark, in charge of the Waipio substation on Oahu.

DEMONSTRATION FARMS.

The work inaugurated on the demonstration farms has met with satisfactory success. At the small substation in Hilo attention has been devoted chiefly to the study of varieties of taro, the various methods of propagating these plants, the effect upon yield from planting at different distances apart, and the results obtained from the use of different combinations of fertilizers. Gradually, also, a collection is being made of the known taro varieties for the purpose of determining which names are synonyms and which varieties can really be distinguished by persistent horticultural characteristics. The results of the taro work at Hilo will be ready for publication in the near future. In addition to the taro experiments at Hilo, attention has been given to banana cultivation, particularly in determining the proper planting distance to be used in that climate and in determining the differences between what seem to be two strains of the Bluefields variety.

At Glenwood, where the station has control of 15 acres of land, a more pretentious equipment has been secured and a much greater variety of experiments is being carried on. The neighborhood of Glenwood seems to be best adapted to dairying, and for this reason a dairy equipment has been secured for the purpose of determining the various conditions which will conduce to the largest profit from butter making in that locality. A great variety of forage plants is being tested out, and the equipment of modern butter-making machinery

will enable the substation to produce butter for sale on the Honolulu market. One of the objects of the dairy work at this substation is to bring the various dairymen together for the purpose of ultimately establishing a cooperative dairy association among them which can take over the practical work along this line and secure to its members greater profits from butter making than are now secured.

The soils of the Glenwood station are of peculiar character and require special study to overcome the unfavorable effects of excessive rain and lack of an efficient temperature for plant growth. In order to determine to what extent the unsatisfactory growth of various plants in that neighborhood is due to local climatic conditions, a number of pot experiments have been planned to be carried out on the station grounds in Honolulu with soils taken from the Glenwood substation.

At the rubber substation in the Nahiku district of Maui attention has been devoted chiefly to the use of intercrops between rubber, planting Ceara cuttings from the most heavily yielding trees, the cultivation of awa, the tapping of Ceara, and the extraction of kukui-nut oil. It has been found that awa does not thrive well when planted in cultivated soil without the benefit of shade. Further experiments will be carried on under partial shade of rubber trees or in the neighboring forest. Broom corn planted between young Ceara rubber trees produced a good yield of satisfactory brush. One acre has been planted with 200 cuttings from Ceara trees which had shown themselves to be exceptionally heavy producers of latex. It is hoped that from these a uniform set of trees will be obtained which will all be high yielders. Nearly all possible methods of tapping Ceara have been tested, with the result that the cost of collecting rubber has been greatly reduced below the figures obtained in previous experiments reported by this station. Moreover, the machinery now used in preparing rubber yields a better product with a lower percentage of resin, protein, and ash. It appears that these impurities are reduced in percentage in proportion as the pressure is increased between the rollers of the mangling machine.

On the Homestead substation about 2 acres are devoted to varieties of peaches. This fruit thrives especially well on Kauai and is a favorite tree in the dooryards of the homesteaders. A number of highly recommended varieties of peaches were obtained from Florida for testing at the substation. At present they are doing well. Cultural and fertilizer studies are also being carried on with pineapples, there being 1 acre devoted to this crop at the substation. In addition to peaches and pineapples attention is being given to onions, Irish potatoes, sweet potatoes, corn, and a considerable variety of other garden vegetables. The work of this substation has been almost altogether of a practical nature. It has attracted the atten-

tion of the homesteaders on the island, and the superintendent has been able to spread much useful information regarding cultural methods, varieties, spraying for fungus diseases and insects, and miscellaneous information of a practical nature.

At the Waipio substation on Oahu the tests thus far have been for the most part along the line of dry farming. During the past season the drought was so unusually prolonged that most of the crops were put to a severe test. Onions were unable to mature bulbs of marketable size, jack beans grew fairly well even when planted during the progress of the drought, and Irish potatoes, sweet potatoes, sorghum, and broom corn were badly affected by dry weather. Of all the legumes tested at Waipio, the velvet bean endured the drought best. Where no windbreak protection was offered to cotton at Waipio it did not mature a satisfactory crop, partly on account of the cool nights and partly on account of the excessive evaporation of the moisture in the soil during the constant trade winds.

ENTOMOLOGICAL INVESTIGATIONS.

The chief efforts of the entomologist during the year were devoted to a study of the Mediterranean fruit fly, mosquitoes, certain parasites of the cotton bollworm, algaroba bean weevils, and scale insects. The practical work in combating the Mediterranean fruit fly has been carried on under the auspices of the Territorial government. The entomologist and the special agent in charge of this station, however, have been consulted and have taken part in all of the active measures which have been adopted. According to the present plan of the campaign the parasites of the Mediterranean fruit fly and cotton bollworm which it is hoped to obtain in Africa will be handled, bred, and distributed by the entomologist of this station. In addition to the usual breeding experiments to determine the variety of fruits affected by the Mediterranean fruit fly, considerable attention has been given to trapping and to the use of a poisoned spray in combating the fruit fly. A number of trips were also made to the Kona coffee district to ascertain the extent of infestation of coffee with fruit fly, the amount of damage actually done by the fly, and to initiate practical measures for controlling the prevalence of the pests in the coffee orchards.

Some attention was given to the study of the life histories and habits of the three species of mosquitoes which are known to occur in the Territory. The immediate occasion for taking up this work was the fear of a possible outbreak of yellow fever on account of the occurrence of the yellow fever mosquito. It was soon found that the yellow fever mosquito was much less common than (*Stegomyia*) *Aëdes scutellaris*, although the latter species was apparently introduced into Hawaii later than the yellow fever mosquito. Much useful informa-

tion was collected regarding the habits of all three species of mosquitoes, particularly with reference to the situations under which the larvæ breed.

HORTICULTURAL INVESTIGATIONS.

The energies of the horticultural department have been devoted largely to the study of pineapples and methods of propagating the avocado, mango, papaya, and hibiscus. The importance of the pineapple industry of Hawaii is growing greater day by day. The output of canned pineapples, which it was feared two years ago had almost reached the limit of the market for this product, has been greatly increased, and arrangements are now being made to nearly double the area devoted to pineapples. The demand for canned pineapples has taken all of the product which could be supplied and seems to warrant this great extension of the industry. Pineapples are second only to sugar cane in commercial importance in Hawaii. The quality of the product has remained uniform, owing to the fact that there are only two commercial varieties of pineapples in Hawaii and that these varieties are of quite similar nature. Recent observations, however, indicate that these varieties have become mixed on nearly all of the plantations and that one of them is decidedly inferior to the other. The inferior variety apparently came from Queensland, while the superior one is apparently the true Smooth Cayenne. The growers are gradually eliminating the less desirable variety. A press bulletin [1] covering the various cultural and marketing features of pineapples was published during the year. Continuation of experiments in methods of propagating the avocado and mango has developed the fact that these fruits may be inarched or budded almost with as much facility as is known to be the case with fruits of temperate climates. The difficulties which had hitherto made the propagation of superior varieties of avocados and mangoes uncertain are rapidly disappearing.

Similarly with papayas there is a good prospect now that strains of seed will soon be obtained which will show almost a complete uniformity in product. Hitherto this has been far from the actual state of affairs. Much seed obtained by the method of crossing male and female flowers showed a variation which was difficult to control and the products of which could not in any case be predicted.

On account of the restrictions placed on bananas by the recent California quarantine law, it has been found necessary to take up in a systematic manner the methods of packing, which promise to make possible the shipment of bananas to California without danger from scale insects and without injury to the bananas. At present it is hoped that the cooperation of the steamship companies can be obtained in furnishing facilities for shipping bananas without any packing around the bunches. It will then be possible to inspect the

[1] Hawaii Sta. Press Bul. 36.

bunches more effectively and conveniently and to avoid the heating and other injurious effects of the various kinds of packing which have hitherto been used.

During the coming year it is hoped to bring some of the work which has been in progress with hibiscus to a conclusion and to publish the results in bulletin form.

CHEMICAL INVESTIGATIONS.

One of the chief lines of work carried on by the chemical department has been a study of the function and distribution of manganese. Some of these results were published during the year in bulletin form.[1] The work of the station on manganese soils is being closely followed by pineapple growers. It appears impossible by any method thus far adopted to grow pineapples successfully on soils which contain more than 2 per cent of manganese. On highly manganiferous soils not only do the leaves turn decidedly yellow or even whitish but the fruits are pink rather than of the normal color and are too acid or otherwise disagreeable in flavor. In selecting new areas for the extension of the pineapple industry the prospective growers have had manganese determinations made in order to avoid the areas in which a high percentage of manganese is found.

Evidence is accumulating from time to time of the importance of a reasonable balance between lime and magnesia in the soils of Hawaii. In some soils the ratio is greatly disturbed by the excessive prevalence of magnesia and in others by an excess of lime. Satisfactory results can not be obtained on either type of soil with the majority of crops. Since the chief injurious effect of manganese seems to be in causing plants to absorb too much lime and too little magnesia, a systematic set of experiments has been planned to determine whether the effects of manganese can not be overcome by adding magnesia to such soils. This question will be thoroughly investigated in a series of pot experiments and on a commercial scale in the pineapple fields.

In decorticating sisal a large amount of waste pulp is obtained of which no economic use has been made in Hawaii. A request was made upon the station to investigate the possible utilization of this pulp. The chemical work was done by the assistant chemist and resulted in determining that the greatest practical value of this pulp was for fertilizing purposes. Sisal removes large quantities of mineral plant food from the soil which can all be returned by the use of the pulp as a fertilizer. The pulp will also add a quantity of humus to the soil. One of the striking scientific results of this investigation was the determination of lactic acid as the normal vegetable acid of sisal. The percentage of acid increases from the base to the tip of

[1] Hawaii Sta. Bul. 26.

the leaf. It is not likely that the acid can be extracted from the pulp with profit. The trouble which the presence of the acid has caused in corroding machinery has largely been overcome by the use of gun metal in the place of iron.

A special study has been made of sulphur and chlorin in the rice plant. Many difficulties have been met with in determining the sulphur, and particularly on account of the occurrence of sulphur in gas in the laboratory. This trouble was overcome by the use of alcohol lamps in the place of gas. When ammonium sulphate was used in pot cultures in sterilized silica sand it was found that the assimilation of ammonia and mineral sulphur took place in such proportions as to indicate clearly that the plant takes up ammonium sulphate as such.

In testing the effect of various fertilizer combinations on taro it was found that the best form in which nitrogen can be applied is ammonium sulphate or an organic form of nitrogen. The effect of nitrate of soda was in some cases equally marked in so far as the total yield was concerned, but it required a much greater weight of taro to produce the same amount of poi when nitrogen was applied as nitrate of soda.

A special examination of Hawaiian soils is being made for the purpose of determining the form in which nitrogen normally occurs in the soil. It appears from preliminary work that the amount of ammonia in certain soils may be 100 times that of nitrate. This problem is of great importance in the rational treatment of our soils, and its study will be continued during the coming year.

Chemical work on various rubbers has been prosecuted in cooperation with the rubber substation on Maui. In addition to work in determining the percentage of resin, ash, protein, and true rubber gum in Ceara and Hevea rubbers, a study has been begun of a new rubber product from *Euphorbia lorifolia*. This tree covers an area of about 6,000 acres in the Kona district of Hawaii, and yields a large quantity of latex, which can be coagulated only by use of heat or alcohol. The dry matter of the latex contains 14 to 17 per cent rubber and about 60 per cent of a resin which appears to be nearly, if not quite, identical with chicle gum.

In cooperation with the Philippine Bureau of Science the chemical department made observations during the year on the actinic power of the sun, with the interesting result that the actinic effect of the sun is highest at the spring and fall equinoxes and lowest at the summer and winter solstices.

AGRONOMICAL INVESTIGATIONS.

Cotton continues to occupy the interest of a considerable number of planters. It has been quite conclusively proved that this crop does not thrive well on the upper lands unless well protected against

trade winds nor in any locality where the temperature is relatively low. On the other hand, excellent results in yield and quality have been uniformly obtained at sea level and in protected localities on the leeward side of the various islands. On account of the fact that Caravonica cotton is less susceptible to attack of the pink bollworm than Sea Island there is a tendency to grow Caravonica cotton chiefly. The prices obtained for this cotton have ranged from 18½ to 20 cents, and a report received from one mill states that the fiber is equal to the best rough Peruvian. In actual strength Caravonica lint appears to be superior to all other varieties of which breaking tests have been made. From a comparative test made by a mainland cotton mill it appears that the value of Caravonica lint obtained from the saw gin is so nearly equal to that from the roller gin that the economic considerations are in favor of the use of a saw gin.

Yields obtained from rices imported from Japan have continued to be satisfactory. Milled samples of this rice have been distributed among various inhabitants of the Territory who were interested in comparing their culinary qualities. There is a growing belief that these rices raised in Hawaii from Japanese seed are practically identical with rice directly imported from Japan. A systematic study is being made of the forage grasses of the Territory. In addition to the species which were native to Hawaii and those which were introduced long ago, many species have been brought in from various tropical and temperate climates to test their adaptability to our wet and dry ranges. The experiments have taken various forms. In some cases the seed was simply sown on the range without any previous preparation, being scattered upon the natural sod of the range. On at least one ranch elaborate planting operations have been carried on during which the ground was plowed and thoroughly prepared before seeding. These operations while relatively expensive promise to give economic returns in forage.

MISCELLANEOUS.

Dynamite has been commonly used for many years on the station grounds in preparing soil for planting trees. This has been found to be the cheapest method by which good soil conditions can be given for the extension of tree roots. During the year a special grade of dynamite was tested in plowing heavy soils for pineapples, in loosening the soil about the roots of growing trees, in improving the drainage in lawns, and in furnishing an outlet for water in small sink-like areas in which the surface water tended to collect. These tests have in all cases shown the large range of applicability of dynamite to farming operations and its effectiveness and economy.

Among the unusual feedstuffs which are used in Hawaii mention may be made of honohono, algaroba bean meal, soy bean cake, and

tree fern trunks. In the extremely wet district of Glenwood, Hawaii, honohono has been found to be one of the best forage crops for dairy cows. It ratoons readily and rapidly without particularly diminishing the yield if stable manure be spread over the ground as fast as the crop is cut off.

While a special machine had been patented for the preparation of a meal from the algaroba bean, the use of the machine was not pushed in a commercial way and great quantities of the beans were being allowed to go to waste. One of the feed companies of Honolulu has at last made arrangements to secure another machine for grinding algaroba beans. This machine is essentially identical with one of the types of alfalfa meal mills. A very satisfactory product is produced, and arrangements have been made to lease land covered with algaroba and to purchase beans on a large scale. It is believed that this product will to some extent take the place of rolled barley, which is now imported in large quantities into the Territory.

The product remaining from the manufacture of soy sauce is a cake containing a high percentage of the usual nutrients in feeding stuffs. The only disadvantage connected with this feeding stuff is the great amount of salt which it contains. It has been found, however, that this can readily be removed by water, leaving a product which has proved valuable for feeding to pigs.

An analysis was made of the common tree fern trunk which occurs in large areas in the mountains. This trunk is widely used as a pig feed either raw or after being cooked. The greater portion of the trunk is of a starchy nature and is much relished, particularly after being boiled. Near the volcano of Kilauea some of these trunks are cooked by being placed over steam cracks.

Among the lines of investigation which have been undertaken and are still unfinished mention should be made of the disease of chickens caused by the prevalence of Manson's eye worm, the extraction of kukui-nut oil, a general soil survey, a study of artificial breeding methods with bees, and a horticultural investigation of hibiscus.

REPORT OF THE ENTOMOLOGIST.

By D. T. Fullaway.

The entomologist was absent in the island of Guam during the early part of the fiscal year, returning to Hawaii on November 3. The accompanying report covers the entomological work done from that date to the end of the fiscal year—a period of about eight months. The routine work of the office, however, was attended to throughout the year. Among other duties performed, numerous inquiries in regard to insect pests were answered personally or by letter. The insect collections of the station were adequately cared for, much material added, and the whole rearranged in new cabinets (following the arrangement in the Fauna Hawaiiensis).

Investigations undertaken in this period were largely in response to pressing demands of the moment, and little opportunity was enjoyed for systematic study of the more important field-crop pests. Some observations of a miscellaneous nature are subsequently noted.

A threatened epidemic of yellow fever, early in November, made desirable a study of the local mosquitoes, which was undertaken by the station. The investigation extended over several months and disclosed much new and useful information concerning the mosquitoes. In publishing the results of the investigation, the writer desires to acknowledge his obligation to the entomological staff of the Sugar Planters' Station, and especially to Mr. Swezey, for much of the material.

MOSQUITOES.

Three species of mosquitoes are found in the Hawaiian Islands—*Culex quinquefasciatus* (*C. fatigans*), the common night mosquito, and *Aëdes calopus* (*Stegomyia fasciata*) and (*Stegomyia*) *Aëdes scutellaris*, usually referred to as day mosquitoes—all three introduced with shipping within the memory of the Hawaiians. From the focal points of introduction the species have spread generally throughout the islands, and in the presence of the conditions requisite for their development are found everywhere from the coast far up into the mountains. The night mosquito differs greatly from the day mosquitoes not only in habits but in the appearance of the larvæ and the adults, while the two day mosquitoes are generally much alike, with certain small distinguishing characters.

NIGHT MOSQUITO.

The night mosquito is a typical culicine and has a wide distribution in the Tropics of both hemispheres. The localities given by Theobald[1] are: Ceylon, Burma, Straits Settlements, China, East Indies, Japan, West Indies, South and Central America, southern part of North America, Natal, Mombasa, Pemba Island (East Africa), Zanzibar, Egypt, Sudan, British Central Africa, Senegambia, Australia, Mauritius, Seychelles, Sarawak, Fiji, Siam, India, Cape Town, Delagoa Bay, Africa, Honolulu. The exact date of its introduction in these islands is now disputed. The historian Alexander states on the testimony of old residents that it was brought to the islands on the ship *Wellington* in 1826. On the other hand, Kamakau, one of the older Hawaiian historians, states that fleas and mosquitoes were unknown in the Hawaiian group until the arrival of Cook's ships (1778–79), implying that they were introduced then. From the evidence adduced, it would seem that the later date is probably correct. For many years this was the only species of mosquito found here, the day mosquitoes coming much later. The species, as already stated, is found in the mountains as well as along the shore (for the simple requirement of its existence, the presence of standing bodies of water, is a universally prevalent condition), and wherever it breeds in large numbers it is the scourge of all unprotected persons at night. The eggs (Pl. I, 1) of this species are laid in rafts several millimeters long, comprising several hundred eggs placed on end and standing together side by side. The eggs taper slightly toward the upper end, so that the upper surface of the mass is a trifle concave. The raft is laid on the surface of the water and is perfectly buoyant. After a day or two the eggs hatch and several hundred tiny "wrigglers" of less than a millimeter's length emerge from the lower end of the respective eggs. These wrigglers, or larvæ, are structurally fitted for an aquatic life. They assume an upright position in the water with head down, jaws busily sweeping food into the mouth, and the respiratory apparatus, which in this mosquito opens externally through a siphon projecting from the penultimate segment, slightly elevated above the surface film. It spends much of the time at the surface, but occasionally makes excursions to the bottom, especially when disturbed, moving by vigorous contortions of the body. It grows in size, and molts. When several days old it becomes very active, going often to the bottom in search of an abundance of food. After several molts and when 10 to 15 days old and about 5 millimeters long, the larva transforms into a pupa, quite different in form, more consolidated and resembling in shape the adult fly's body. The head and thorax are joined and

[1] Monograph of the Culicidæ. London, 1910, vol. 5, p. 383.

rather swollen; the abdomen is represented by a tail with swimming flaps. The breathing tubes are now on the back near the head, and the body assumes a position in the water which allows these to protrude through the surface film. The pupa is equally active, but as it does not feed it moves only when alarmed. In two days the mature form emerges, leaving its pupal case behind in the water. These mate, and the cycle is continued. Twelve rearings of this species, including many hundred individuals, gave the following records: Egg stage, 1 to 2 days (mostly 1 day); larval stage, 11 days; pupal stage, 1 to 4 days (mostly 2 to 3 days). This gives an average life cycle from deposition of eggs to adult free flying mosquito of 15 days. It was found (with all three species) that a scarcity of food in the aquaria extended the larval life, which could easily be produced to two or three months, without otherwise interfering with the normal development of the species. This species breeds in fresh as well as in muddy and contaminated water and is the typical mosquito of the mud puddle. It was found in perfectly fresh drinking water, in the more or less brackish water of the duck ponds, in the muddy water of ponds, pools, gutters, drains, and in water contaminated by fecal matter, soap, rubbish, and other extraneous matter; it was found in such small collections of water, in tin cans, cups of flowers, small puddles, that without renewal from some source, the quantity of water present could not withstand the losses of evaporation through the larval period; yet it is able to breed in all of these situations in spite of their disadvantages, provided its physiological activities are not interfered with.

The larva (Pl. I, 2, 2a) can be recognized from the following description:

Length 5 to 6 mm. Dark grayish, head more or less black. Thoracic segments almost as wide as the head, behind the thorax body slenderer and tapering. Anal siphon also long and slender, 1.2 mm. in length, greatest width 0.3 mm. Head more or less cubical, eyes black, mouth brushes as usual. The antennæ are long, 0.5 mm., about one-third the length from distal end the shaft becomes constricted, and in the notch thus formed is set a tuft of hairs; beyond the constriction the shaft is much thinner, and at the tip also there are two or three hairs. The labial plate bears a number of spines. The thoracic and abdominal segments laterally bear tufts of hairs which are longer on the thorax. The last abdominal segment bears a conspicuous ventral brush and dorsally there is a tuft of five long hairs. The siphon has a pair of hair tufts at about half its length, another pair a trifle before, more than a third the length from the proximal end, another pair of small tufts less than a third the length from the distal end and a fourth small pair somewhat before these and moved to one side out of line. There is a row of 13 three to four toothed spines on the siphon extending from the proximal end to the first pair of tufts. The lateral comb on the penultimate segment consists of more than 30 plates.

Attention is called to the shape of the anal lobes in the pupa. (Pl. I, 3.)

The adult (Pl. I, 4) is described as follows:[1]

Thorax brown, with two distinct dark lines on the denuded surface, covered with pale golden curved scales and with two more or less distinct bare parallel dark lines and three rows of dark bristles, ornamentation variable. Abdomen dark brown to black, with basal white or pale creamy curved bands and white lateral spots; venter white or yellow scaled. Legs dark brown; bases of the femora and coxæ pale, knee spot and sometimes the apex of the tibia with a faint yellow spot; ungues of the female equal and simple; in the male the fore and mid ungues are unequal and uniserrated, the hind equal and simple. Wings with the first submarginal cell longer and narrower than the second posterior cell, its stem variable in length, never less than one-quarter the length of the cell; posterior cross vein distant twice (or more) its own length from the mid cross vein.

In view of Dr. Graham's investigations, this species is believed to be the intermediate host of the sporozoan parasite causing dengue fever.

DAY MOSQUITOES.

The day mosquitoes (*Aëdes calopus* and (*Stegomyia*) *Aëdes scutellaris*) are essentially different in appearance from the night one, and the two would never be confounded. Between themselves there are some striking small differences which distinguish them at once. The white markings on the back (dorsum of thorax) of *Aëdes calopus* are in the form of a lyre, while the marking on the back of *Aëdes scutellaris* is a single white line running down the center. The immature forms also present microscopic differences. The comb in the larva of *Aëdes calopus* is composed of 8 teeth with trifid apices, while the pupa has anal lobes dentate margined. The comb of the *Aëdes scutellaris* larva is composed of 10 unidentate teeth, and the anal lobes of the pupa have hairy margins. The Stegomyia larvæ differ radically from the Culex larvæ in both structure and habits, so that all three species are readily distinguished in any stage of their existence.

The exact date of the introduction of the day mosquitoes is not established, but it is quite certain that they came much later than the culicine and, from all accounts, during the lifetime of some of the present generation.

The habits of the two day mosquitoes are very similar. They prefer clear fresh water; at least, they are found almost altogether, if in natural collections of water, in clear water, never in puddles or polluted water, and while they are found along with *Culex quinquefasciatus* in clear standing water in troughs and other artificial containers they are not found if the water in such containers has become foul or turbid. They are very common around habitations, where the larvæ are usually found in water butts, troughs, or other containers of rain water or uncontaminated faucet water. They are

[1] F. V. Theobald. Monograph of the Culicidæ. London, 1901, vol. 2, p. 151.

also found in permanent pools along stream beds in the gulches and in water holes in the mountains. The adult fly differs radically from the culicine in habits, since it is almost entirely a day flyer, while the culicine stalks out in the night and can not be induced to bite in the daytime. It is also largely found in dark and shady places; in the woods it rests on vegetation, biting viciously when disturbed; in houses it gets in the dark recesses of the room or its furniture and comes forth from these retreats to bite the exposed parts of the body as soon as one's presence is sensed.

The life history of the day mosquitoes is somewhat as follows: They lay their small, black, torpedo-shaped eggs (Pl. I, 5) singly to the number of 40 or 50 on the surface of water, or, according to Dr. H. W. Henshaw, who made careful observations on the mosquitoes here some years ago, on the sides of containers, a quarter of an inch or so above the surface, where the eggs will withstand considerable desiccation (before the rising water floats them off) without its interfering with their hatching. The eggs hatch in five or six days. The larvæ in the water are of very similar appearance to the culicine larvæ, except for the short siphon and untapering body. Their habits, however, are different. They feed very largely at the bottom of containers or along the sides, seem to seek the darkest recesses, and do not come as often to the surface to breathe. For this reason they are a rather difficult mosquito to collect. The larval development is usually completed at the end of from 15 to 20 days, when the larva transforms into a pupa. The pupal development occupies two days, and from the pupa emerges the adult free-flying mosquito, male and female, which mate and repeat the cycle.

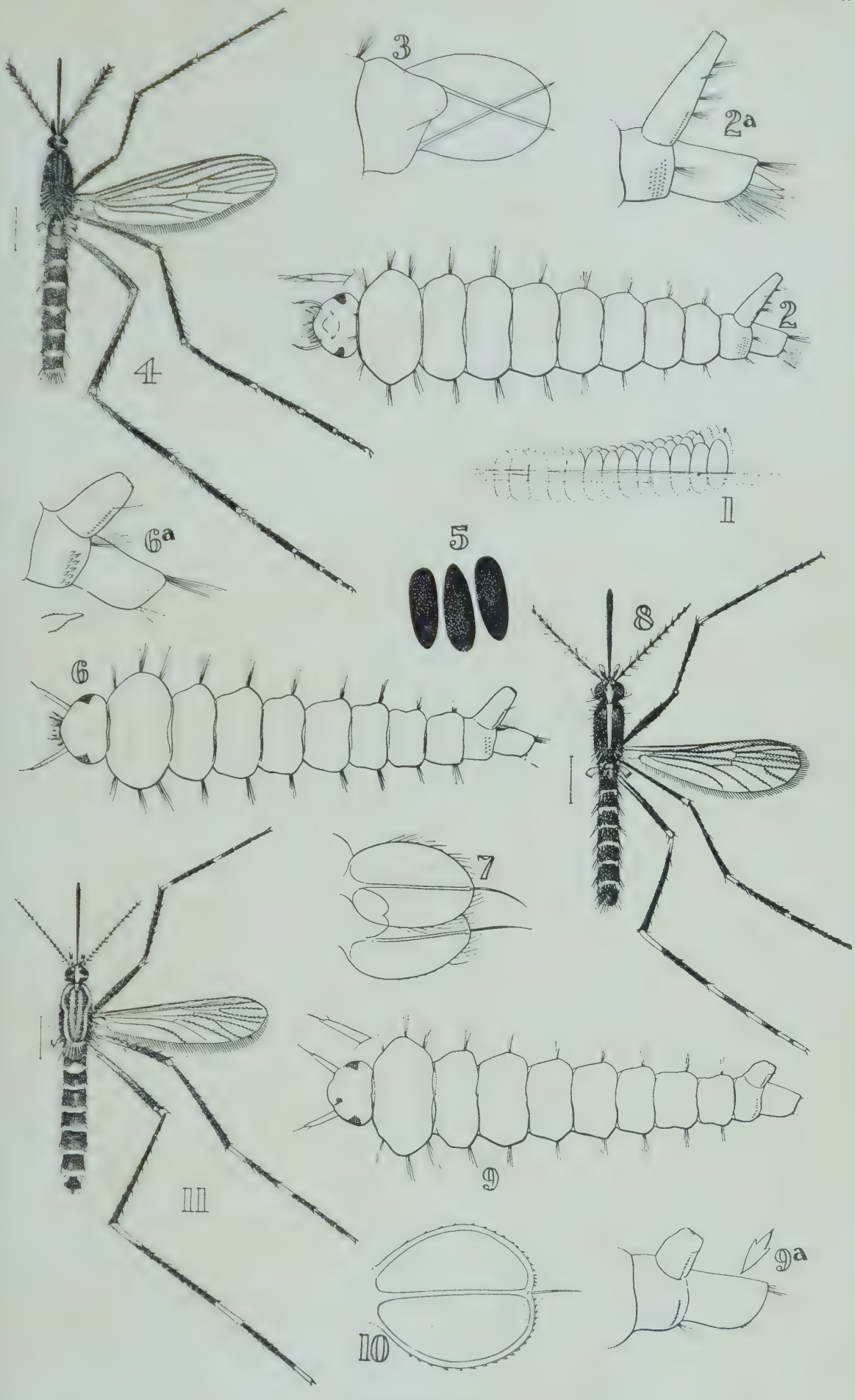
AËDES SCUTELLARIS.

The distribution of (*Stegomyia*) *Aëdes scutellaris* as given by Theobald [1] is as follows: India, Ceylon, Upper Burma, Siam, Penang, Perak, Selangor, Singapore, Christmas Island, Amboina, North Borneo, Sarawak, Celebes, British New Guinea and New Guinea generally, Foochow, etc., China, Hongkong, Formosa, Japan, Philippine Islands, Fiji, Pitcairn Islands, Seychelles, Mauritius, Guam (Fullaway).

Eight rearings of this species, including many hundreds of individuals, gave the following records: Egg stage 5 to 6 days, larval stage 15 to 24 days (one record 17 days, another 61 days [larval period protracted by reduction of food]), pupal stage 1 to 4 days (mostly 2 days).

It was found, as many other investigators have claimed, that permitting the adult to suck blood in some way accelerated the forma-

[1] Monograph of the Culicidæ. London, 1910, vol. 5, p. 155.



MOSQUITOES.

1, 2, 2a, 3, 4, eggs, larva, pupa, and adult of night mosquito; 5, eggs of day mosquitoes; 6, 6a, 7, 8, larva, pupa, and adult of *Aëdes scutellaris;* 9, 9a, 10, 11, larva, pupa, and adult of *Aëdes calopus.*

tion and deposition of eggs. All the specimens bred from egg to adult in the laboratory were allowed to feed previous to confinement, and none otherwise confined produced eggs. While this is not necessarily conclusive evidence as to the necessity of this performance to the production of eggs, it corroborates the observations of other workers and the idea seems altogether plausible.

Aëdes scutellaris, like the other mosquitoes in Hawaii, has a very general distribution, but out of the writer's experience the impression was gathered that it is the commoner of the two day-flying mosquitoes, and was always found in great abundance at the mouths of the numerous gulches behind the city of Honolulu in the belt of rising ground occupied by guava, lantana, and klu, where the larva breed in the pools formed by the receding water of drying-up creek beds, the adult flies finding shelter in the thick underbrush. It also breeds commonly around habitations on the outskirts of the city.

The larva (Pl. I, 6, 6a) can be recognized from the following brief description:

Length 6 mm. Grayish, head more or less dark. Thoracic segments almost as wide as the head, the body beyond scarcely tapering. Anal siphon moderately long, 0.72 by 0.36 greatest width. Head more or less cubical, eyes black, mouth brushes as usual, antennæ moderately long, tapering slightly, but of more or less uniform width throughout. A hair on the inner margin at about the middle and a stout spine and several hairs at the tip. Abdominal segments with a pair of hairs caudally on each segment. Ventral brush and dorsal tuft on ultimate segment thin. Pecten on anal siphon with 6 to 13 teeth in a row, the comb composed of 10 unidentate spines with small barbs at base.

Pupa (Pl. I, 7). The hairy margin of the anal lobes is peculiar.

The following brief description of the adult (Pl. I, 8) is sufficient to distinguish the species here:

Throax black, with a median silvery stripe; abdomen with silvery white basal bands; legs black, tarsi basally white banded, last joint of the hind legs pure white.

There is nothing in the literature of mosquitoes to warrant the statement that this mosquito is concerned in the transmission of yellow fever. Its distribution would apparently deny any such claim.

AËDES CALOPUS.

The distribution of *Aëdes calopus* as given by Theobald [1] is as follows: India, Upper Burma, Ceylon, Siam, ports in Malay Peninsula, Philippine Islands, Celebes, New Guinea, Java, Japan, Hawaiian Islands, Fiji, Pitcairn Islands, Samoa, generally in Africa, Southern United States, Mexico, Central America, Panama, west coast of South America, British and French Guiana, Trinidad, Brazil, West Indies, Southern Europe in Portugal, Italy, Spain, Gibraltar, Teneriffe, Greece, Cyprius, Australia in Queensland and Victoria, etc.

[1] Monograph of the Culicidæ. London, 1910, vol. 5, p. 158.

Three rearings of this species, including many individuals, gave the following records: Egg stage, 4 days; larval stage, 17 days; pupal stage, 2 to 3 days.

This species is more or less rare; at least, in the writer's experience, it is not nearly so abundant as either *Aëdes scutellaris* or *Culex quinquefasciatus*. It was found chiefly around habitations, breeding in artificial containers of rain water or uncontaminated faucet water. Dr. Perkins states that on several occasions he found it in large numbers at rather high elevations, and the specimens on which it was first recorded from the islands were taken in the Waianae Mountains at 1,500 feet. Its distribution is therefore, like that of the other species, rather general, but it is not nearly so abundant as the other two species.

The larvæ (Pl. I, 9, 9a) can be recognized from the following description:

Length 5 mm. Very similar to *Aëdes scutellaris*. The anal siphon, however, is short and thick, 0.72 mm. by 0.5 mm. greatest width, and its pecten is composed of 10 to 15 toothed spines. The lateral comb of the penultimate segment contains 8 plates with trifid apex arranged in a single slightly curved line.

Pupa (Pl. I, 10). The margin of the anal lobes is distinctly serrate and without hairs.

The following brief description from Theobald [1] will distinguish the adult (Pl. I, 11):

Thorax dark brown to reddish brown, with two median parallel pale lines and a curved silvery one on each side, a small line in front between the two median ones. Abdomen black, with white basal bands and lateral spots. Legs black, with basal white bands, last joint of hind legs pure white.

The experiments of Maj. Walter Reed, United States Army, in Cuba, proved conclusively that this species is responsible for the transmission of yellow fever, probably acting as the intermediate host of an ultramiscroscopic parasite which produces the disease.

NATURAL ENEMIES OF MOSQUITOES.

There are no known specific parasites of mosquitoes. Among the natural enemies of these insects, which by feeding upon them tend to reduce their numbers, the most efficient are dragon flies and fish. There are several species of dragon flies in Hawaii which as nymphs prey upon the larvæ and pupæ in the water, and as mature free flying insects prey upon the imago or adult mosquito. Among the native fish which feed upon mosquitoes are the different species of gobies, locally known as oopu, which are found in all the streams and small ponds. There are also in Hawaii the introduced gold fish, which is very useful in aquaria, watering troughs, tanks, and other artificial

[1] Monograph of the Culicidæ. London, 1901, vol. 1, p. 289.

pools containing more or less clear water, and the top minnows (Pœciliidæ), which were introduced some years ago from Texas for the specific purpose of destroying mosquito larvæ. The latter fish have proved very efficient mosquito enemies and along with the dragon flies effectively control the production of mosquitoes in the large low areas near the sea which are devoted to rice and taro growing or covered with the usual swamp vegetation. As the cultivated fields are frequently drained, they must often be restocked with fish. The fish, too, are often checked by the choking up of waterways and in these isolated bodies of water mosquitoes can develop with perfect freedom.

REPRESSION OF MOSQUITOES.

Experience has shown that it is economically possible by well-directed efforts to destroy large numbers of mosquitoes in their aquatic stages and considerably lessen their annoyance. The method universally followed is to remove or treat the bodies of water in which the mosquitoes are found to breed. The unlimited details of anti-mosquito work have their foundation and beginning in the accomplishment of this simple purpose. It usually, however, becomes apparent in any work of this sort that many breeding places of mosquitoes have a very temporary existence and are constantly being obliterated, renewed, or altered—such breeding places, for instance, as tin cans, flower cups, or mud puddles—and that these breeding places require constant and continuous attention to effect any real benefit. This militates greatly against the value of sporadic campaigns against mosquitoes. The almost prohibitive expense of the repetition of work which could be done once for all time also enhances the value of permanent drainage of large bodies of water. If future work of this sort is attempted in Honolulu it is respectfully suggested to the public and its authorized agents that part of the funds be set aside for continuous permanent work, such as drainage and reclamation of lowland, rice fields, taro patches, etc.; that ordinances be secured making the maintenance of bodies of standing water in which mosquitoes might breed on premises a nuisance whose continuance would be punishable by fine; and that the funds not used in permanent or absolutely necessary emergency work be conserved to provide for a regular and continuous force of inspectors which would attend to the enforcement of the law as to owners and lessees of premises and look after the otherwise unattended territory to remove all possible breeding places of mosquitoes.

PINK BOLLWORM OF COTTON.

Some attention has been given to the pink bollworm (*Gelechia gossypiella*), which is now recognized as an important factor in the successful production of cotton in Hawaii. A great deal was expected

of the cultural methods of control, but after the second year's trial the results seem only partially assuring, where the time and amount of rainfall is variable. One field of Sea Island cotton cut back in December was again in full flower in February and became so badly infested by bollworm that it was necessary to plow up and burn it to save adjacent fields.

In a bulletin[1] of this station the writer recorded the braconid, *Chelonus blackburni*, as a parasite of this species. Several new records are now offered. In a lot of infested bolls brought in in December there were found numerous specimens of a bethylid, believed to be [*Goniozus*] *Parasiorola cellularis*, presumably coming from larvæ of the bollworm. To determine the suspected relationship specimens were confined in breeding jars with larvæ of *G. gossypiella*, and after a short time the bethylid proceeded in its customary manner to paralyze the gelechiid larva and lay eggs upon it. Several generations of the parasite were bred and the length of the several stages noted, as follows: Egg stage 1 day, larva 7 days, pupa 11 days, making the cycle from egg deposition to adult parasite 19 to 20 days. From one to eight eggs were laid on a single caterpillar, but all did not mature. The larvæ usually feed externally, making large holes in the body of the worm, and the development is rather rapid. When full fed they make a small white elongate cocoon (usually spun in clusters where the larvæ were feeding) in which they pupate.

From the same lot of larvæ there were also bred several specimens of the ichneumonid, *Pristomerus hawaiiensis*, previously reported from the sweet potato stem borer (*Omphisa anastomosalis*), and from pupæ, a chalcid, probably belonging to the genus Hockeria, which has not previously been recorded in Hawaii.

The parasitism of all these species is apparently incidental and of rather small extent.

BEAN WEEVILS.

It has long been recognized that the value of the kiawe bean (*Prosopis juliflora*) as a stock food would be greatly increased if the pods were finely ground so as to put the seeds, which are rich in protein, in a digestible condition. With the perfection of machinery for this purpose, the losses occasioned by the bean weevils (bruchids), the larvæ of which largely feed upon the seed, again become a matter of importance. There are now two species of weevils attacking the kiawe bean, *Bruchus prosopis* and *Caryoborus gonagra*—both introduced pests. The work of the former has been known for a long time and the insect is common on all the islands. The latter species was first noticed in 1908 in Honolulu. Since then it has spread over the lowlands of Oahu and has also been found on the island of Kauai, so

[1] Hawaii Sta. Bul. 18.

that there is no reason to doubt that ultimately it will have the same general distribution as the earlier species.

The kiawe bean weevils are more or less familiar insects, but a short account of their life history will probably not be superfluous. The eggs are laid singly on the pods, one female weevil laying many eggs successively over the pod. The eggs are pearly, later turning creamy white, short oval, convex, microscopically reticulate, with distinct margin. There is no definite distinction between the eggs of the two species, and probably they can not be told apart. Those of *C. gonagra* are slightly larger. The egg (of *B. prosopis*) hatches in 10 days. The larva, which is stout bodied, yellowish white with black head, immediately burrows into the pod, often from beneath, so that the exposed portion of the egg is not broken. Making its way through the pulp, the grub finally reaches a seed, eats out its contents, and moves on to another seed—and so on until after 18 to 20 days it is full grown and pupates. After a variable period, usually 10 to 12 days, the pupa transforms into an adult beetle. The complete life cycle therefore covers about 40 days. The two species have been found working together in a single lot of beans. The larvæ of both beetles before pupating make an exit hole for the adult beetle, leaving only a thin film of cortical tissue to be eaten or broken through. These in the case of *C. gonagra* are much more conspicuous on account of their larger size and the thinness of the film. *C. gonagra* larvæ also make a cocoon within which to pupate and usually remain inside the cocoon for 3 to 4 days after becoming fully mature. The adults are easily distinguished, as *C. gonagra* is nearly twice the size of *B. prosopis* and is reddish brown, whereas the latter is more or less grayish marked with black.

An attempt was made several years ago to introduce from Texas certain hymenopterous parasites of the bean weevils, which, if established in Hawaii, would materially reduce the losses occasioned by these insects. Several consignments were received from the southern field laboratories of the Federal Bureau of Entomology, out of which one species (*Heterospilus prosopidis*?) bred by the thousands, and was liberated in several widely removed localities. While it is probably too early to state conclusively that this species has not become established, after three years it has not been recovered, although each year material has been especially bred for this purpose. In the material from Texas, however, was a minute hymenopterous parasite to which little importance was attached at the time the consignments were received, but which has now become established and proves a most valuable check to the multiplication of the weevils. This parasite, which attacks the eggs of the bean weevils, formed a new genus and species of Trichogramminæ and was recently described by

A. A. Girault as *Uscana semifumipennis*.[1] The parasite has already become rather generally distributed, and with the movement of beans from one locality to another will undoubtedly in time be spread over all the islands. The value of this check on the bean weevils will be realized from the results of an examination of a lot of beans recently, in which over 25 per cent of the eggs were parasitized.

SCALE INSECT PARASITES.

In connection with the study of the scale insects (Coccidæ), some attention has been given to the hymenopterous parasites of these and related insects, and an attempt has been made to bring together the records of parasitism in this economically important group, so that they will be available for reference to economic entomologists. This work was greatly facilitated by the loan of specimens in the collections of the Hawaiian Sugar Planters' Experiment Station and of the Board of Forestry and Agriculture, and the writer's thanks are due Mr. E. M. Ehrhorn and Dr. R. C. L. Perkins for many valuable records and suggestions in the elaboration of the material. Two new genera and three new species in the collections are herewith described. The lists which follow the descriptions are intended to present an orderly arrangement of the parasite species with their host relationships, and a table at the end shows the extent of the parasitism of the different species.

APENTELICUS gen. nov.

Near *Pentelicus* Howard, but at once distinguished from that genus by the insertion of the antennæ near the middle of the face. Body short, compact; abdomen small and triangular. Head transverse, lenticular, but not to the extreme degree seen in *Blepyrus*. Front fairly broad, with small thimble-like punctures, face wide, not retracted as in other genera, with rather broad longitudinal carina. Ocelli forming an obtuse triangle, the lateral members a trifle more than their diameter from the eye margin. Antennæ filiform, the broadly expanded scape short, not reaching ocelli; pedicle short, obconic, club not longer than the two preceding funicle joints. Punctuation of the thorax different from that of the head, very feeble. Marginal vein of wings short, less than twice as long as wide, postmarginal and stigmal veins rather short, subequal in length.

Type. The following species:

A. kotinskyi sp. n.

♂. Length of body, 1.17 mm., expanse of wings, 2.43 mm., greatest width of forewing, 0.47 mm. Head on vertex a brilliant metallic green with aeneous reflections, face and cheeks bluish green, eyes and occiput almost black. Ocelli reddish, mandibles brown, palpi yellow, antennæ sordid pale brown. Pronotum and mesonotum with axillæ metallic green, scutellum, mesopleuræ, and abdomen green with bluish reflections, legs pale brown. Body not especially stout, rather completely clothed with short white hairs. Thimble-like punctures on front of head extending on to vortex. Eyes small, widely separated. Antennæ 9-segmented (club undivided), long, filiform, extremely pilose, pedicle less than half the length of first funicle joint, funicle joints

[1] Trans. Amer. Ent. Soc., 37 (1911), No. 1, p. 22.

elongate, first more than twice as long as wide, club small, inconspicuous. Thorax scarcely convex, microscopically reticulate, feeble punctures of mesonotum arranged in more or less definite longitudinal rows, each puncture the point of insertion of a short white hair; scutellum shagreened with a few long hairs apically; mesopleuræ bare. Inner angles of the axillæ widely separated. Abdomen flat, short, acutely pointed at apex, with rather sparse vestiture of very short hairs and two lateral tufts of long hairs basally. Legs fairly stout, shortly and densely pilose. Wings hyaline, marginal vein short, postmarginal vein about as long as stigmal, which is fairly well developed.

Hab. Honolulu, Hawaiian Islands. Bred from *Lepidosaphes* sp.*?*

Adelencyrtus odonaspidis sp. n.

Length, 1.17 mm., wing expanse, 2.25 mm., greatest width of forewings, 0.33 mm. Metallic green, the face, genæ, prothorax, mesopleuræ, metathorax, and abdomen with purplish reflections. Head with face retracted below the eyes and lying in the dorsoventral plane, posteriorly widening to the genæ, which are also well developed. Eyes black, hemispherical, the inner margins almost parallel, but rather widely separated; scrobes semicircular, inner margins forming a well defined carina. Fronds sparsely punctate, bearing whitish hairs; ocelli red and arranged in a triangle, the lateral members close to eye margin. Antennæ brown, basal joint of club dark; 11-jointed, arising not far from mouth border, the scape clavate, reaching anterior margin of face, pedicle obconic, longer than the following four submoniliform funicle joints, two remaining joints of funicle larger, almost quadrate, club somewhat expanded and almost as long as funicle. Prothorax well developed and anteriorly conically produced. Mesonotum flat and with mesopleuræ microscopically reticulate, the former bearing regular longitudinal rows of black hairs. Axillæ narrow, indistinctly meeting at the middle and with the triangular scutellum, which is nearly as long as the mesonotum, shagreened. Metanotum and abdomen smooth, the latter dorsally rather flat, collapsing after death, apex produced to a point. Fore and mid legs pale brown, hind femora black except at base, the hind tibia basally with black annulus. Ovipositor slightly exserted, brown. Wings fuscous with a hyaline band just beyond stigma and an oblique hairless line extending inward from same. Veins black, marginal vein obscured by infuscation but quite long, stigmal vein very short and thick, postmarginal still shorter.

Distinguished from other species in the genus by infuscation of wings.

Hab. Honolulu, Hawaiian Islands. Described from several specimens bred from *Odonaspis graminis* and given by Ashmead the manuscript name of *Amicroterys kotinskyi*.

PTEROPTRICHOIDES gen. nov.

Belongs in the same category as *Pteroptrix* but antennal and wing characteristics are essentially different. Head slightly produced in front and excavated below eyes for insertion of antennæ; ocelli forming an obtuse triangle, the lateral members close to eye margin; antennæ 8-jointed, inserted below the middle of the face, scape long, only slightly swollen, pedicle obconic, less than one-third as long as scape, funicle joints wider than long, the middle one the smallest and only half as long as wide, the entire funicle only a little longer than the pedicle, club large, elongate, joints subequal and fluted, gradually narrowing to a point at apex. Thorax convex, pronotum inconspicuous, mesonotum and scutellum forming a broad carapace, mesoscutar parapsides wedge-shaped, posteriorly very narrow, and much pressed by the advancement of the almost quadrate axillæ. Abdomen short, completely sessile, rounded at apex, ovipositor with prominent, long, thin, flat valves slightly exserted, and extending upward almost to the level of the dorsum. Legs stout, all the tarsi 4-jointed. Forewings with long marginal fringe and sparse discal ciliation, the marginal vein almost as long as the submarginal, the tip reaching middle of wing. Hind wings narrow, with long marginal

fringe and short discal cilia; marginal vein ending at middle of wing, which is there somewhat produced anteriorly.

Type. The following species:

P. perkinsi sp. n.

Length, 0.7 mm., expanse of wings, 1.34 mm., greatest width of forewings, 0.2 mm. Color in balsam dark brown, eyes black, ocelli red, legs pallid. Occiput finely aciculate, the aciculation extending on to vertex, which also bears a few sparse hairs. Forewings clouded basally to apex of the marginal vein, which is thick, ending at middle of wing. Stigmal vein entirely undeveloped.

Hab. Honolulu, Hawaiian Islands. Bred from a coccid (n. g. and n. sp.) on Bombay mango by Mr. Jacob Kotinsky, August 24, 1906.

List of parasites and their hosts.

CHALCIDOIDEA.

ENCYRTIDÆ.

Ectromini.

Parasites.	Hosts.
Anagyrus sp.?	*Pseudococcus* sp.

Encyrtini.

Encyrtus fuscus	*Saissetia hemispherica.*
Encyrtus sp. (with banded ant.)	*Saissetia* sp.
Encyrtus sp	*S. hemispherica.*
	Coccus viridis.

Mirini.

Blepyrus insularis	*Pseudococcus aonidum.*
	P. virgatus.
Aphycus sp.?	*P. calceolariæ.*
Aphycus sp.?	*Lepidosaphes* sp.
Microterys flavus	*Pulvinaria mammæ.*
	P. psidii.
	Ceroplastes rubens.
	Saissetia hemispherica.
	S. nigra.
Apentelicus kotinskyi	*Lepidosaphes* sp.
Adelencyrtus odonaspidis	*Odonaspis graminis.*
Cerapterocerus sp	*Saissetia hemispherica.*
	Aspidiotus sp.?
Hemencyrtus sp.?	*Saissetia nigra.*
Aphidencyrtus sp.?	*Aphis maidis.*
Encyrtus sp.?	*Pseudococcus citri.*

PTEROMALIDÆ.

EUNOTINÆ.

Scutellista cyanea	*Saissetia hemispherica.*

SPHEGIGASTERINÆ.

Tomocera californica	*Asterolecanium pustulans.*
	Saissetia hemispherica.
	S. nigra.
T. ceroplastis	*Ceroplastes rubens.*

EULOPHIDÆ.

ENTODONINÆ.

Astichus sp.	?

APHELININÆ.

Aneristus ceroplastæ	*Ceroplastes rubens.*
Coccophagus orientalis	*Pseudococcus* sp.
	Coccus viridis.
Coccophagus lecanii	*Aspidiotus rapax.*
Encarsia sp.	*Aleyrodes sonchi.*
Thysanus sp.	*Asterolecanium pustulans.*
	Aspidiotus cydoniæ.
Aphelinus diaspidis	*Diaspis bromeliæ.*
	Aulacaspis rosæ.
	Hemichionaspis minor.
	Aspidiotus camelliæ.
Aphelinus sp. (wingless)	*Lepidosaphes* sp.
Pteroptrichoides perkinsi	Coccid (n. g., n. sp.) [Kot.].
Pteroptrichoides sp.	*Asterolecanium pustulans.*
	Howardia biclavis.
Aspidiotiphagus citrinus	*Hemichionaspis minor.*
	Chrysomphalus aonidum.
Eretmocerus corni	*Aleyrodes hibisci.*

ICHNEUMONOIDEA.

BRACONIDÆ.

APHIDIINÆ.

Diaeretus rapæ	*Aphis brassicæ.*
	Macrosiphum sp.

CYNIPOIDEA.

FIGITIDÆ.

EUCOILINÆ.

Eucoila sp.?	*Macrosiphum* sp.
	Aphis sacchari.

List of hosts and their parasites.

COCCIDÆ.

DACTYLOPIINAE.

Hosts.	Parasites.
Asterolecanium pustulans	*Pteroptrichoides perkinsi.*
	Thysanus sp.
	Tomocera californica.
Pseudococcus aonidum	*Blepyrus insularis.*
P. calceolariæ	*Aphycus* sp.
P. citri	*Encyrtus* sp. (Mirine).
P. virgatus	*Blepyrus insularis.*
Pseudococcus sp.	*Coccophagus orientalis.*
Pseudococcus sp.	*Anagrus* sp.?

COCCINÆ.

Pulvinaria mammæ	*Microterys flavus.*
P. psidii	*M. flavus.*
Ceroplastes rubens	*Aneristus ceroplastæ.*
	Microterys flavus.
	Tomocera ceroplastis.
Coccus viridis	*Coccophagus orientalis.*
	Encyrtus sp.
Saissetia hemispherica	*Microterys flavus.*
	Tomocera californica.
	Scutellista cyanea.
	Cerapterocerus sp.?
	Encyrtus fuscus.
	Encyrtus sp.
Saissetia nigra	*Hemencyrtus.*?
	Microterys flavus.
	Tomocera californica.
Saissetia sp	*Encyrtus* sp. (with banded ant.).

DIASPINÆ.

Howardia biclavis	*Pteroptrichoides* sp.
Diaspis bromeliæ	*Aphelinus diaspidis.*
Aulacaspis rosæ	*A. diaspidis.*
Hemichionaspis minor	*A. diaspidis.*
	Aspidiotiphagus citrinus.
Aspidiotus excisus	?
A. camelliæ	*Aphelinus diaspidis.*
A. cydoniæ	*Thysanus* sp.
A. rapax	*Coccophagus lecanii.*
Aspidiotus sp	*Cerapterocerus* sp.
Chrysomphalus aonidum	*Aspidiotiphagus citrinus.*
Odonaspis graminis	*Adelencyrtus odonaspidis.*
Lepidosaphes beckii?	*Aphycus* sp.
Lepidosaphes sp	*Apentelicus kotinskyi.*
	Aphelinus (wingless).

ALEYRODIDÆ.

Aleyrodes hibisci	*Eretmocerus corni.*
A. sonchi	*Encarsia* sp.

APHIDIDÆ.

Macrosiphum sp	*Eucoila* sp.?
	Diæretus rapæ.
Aphis maidis	*Aphidencyrtus* sp.?
A. gossypii	*Aphelinus diaspidis.*
A. brassicæ	*Diæretus rapæ.*

The host relationship of scale insect parasites.

Parasites.	*Asterolecanium pustulans.*	*Pseudococcus aonidum.*	*P. calceolariæ.*	*P. citri.*	*P. virgatus.*	*Pseudococcus* sp.	*Pseudococcus* sp.	*Pulvinaria mammæ.*	*P. psidii.*	*Ceroplastes rubens.*	*Saissetia hemispherica.*	*S. nigra.*	*Saissetia* sp.	*Howardia biclavis.*	*Diaspis bromeliæ.*	*Aulacaspis rosæ.*	*Hemichionaspis minor.*	*Aspidiotus camelliæ.*	*A. cydoniæ.*	*A. rapax.*	*Aspidiotus* sp.	*Chrysomphalus aonidum.*	*Odonaspis graminis.*	*Lepidosaphes beckii.*	*Lepidosaphes* sp.	*Aphis maidis.*	*A. brassicæ.*	*Macrosiphum* sp.	*Aleyrodes sonchi.*	*A. hibisci.*
Anagyrus sp						×																							
Encyrtus fuscus											×																		
Encyrtus sp				×																									
Encyrtus sp											××																		
Encyrtus sp																													
Blepyrus insularis		×			×																								
Aphycus sp			×																										
Aphycus sp																									×				
Microterys flavus									××	×	××	×																	
Apentelicus kotinskyi																									×				
Adelencyrtus odonaspidis																							×						
Cerapterocerus sp											×										×								
Hemencyrtus sp												×																	
Aphidencyrtus sp																										×			
Scutellista cyanea											×																		
Tomocera californica	×										××	×																	
T. ceroplastis										×																			
Aneristus ceroplastæ										×																			
Coccophagus orientalis							×																						
C. lecanii																				×									
Encarsia sp																													
Thysanus sp	×														×	×	×	×	×										
Aphelinus diaspidis																													
Aphelinus (wingless)																													
Pteroptrichoides perkinsi	×													×			×												
Aspidiotiphagus citrinus																													
Erctmocerus corni																													×
Diaeretus rapæ																													
Eucoila sp																													

NOTES ON BREEDING AND IMMATURE STAGES OF COCCINELLIDÆ.

Some work has been done on the identification of the immature forms of the different species of coccinellid beetles, which have considerable interest as enemies of the scale insects, leaf hoppers, plant lice, white flies, etc. The life history of three species has been fully worked out, and the data, together with some miscellaneous notes on these insects, are here presented.

Coelophora inequalis.—This species, which was formerly known by the name of *Coccinella repanda,* has been shown by Dr. Perkins and others to be quite distinct from that species and is now definitely known to be the above. An account of its life history is presented by Swezey in a bulletin of the Hawaiian Sugar Planters' Station.[1]

Coelophora pupillata.—Eggs elongate oval, 1 mm. long, chrome yellow, laid on end on the surface of a leaf in clusters of 5 to 10 or more.

Larva when hatched, 2 mm. long, similar in shape to young larva of *C. inequalis.* Dusky black, white spot laterally on first abdominal segment and a transverse band of white on fourth abdominal

[1] Hawaiian Sugar Planters' Sta., Div. Ent. Bul. 1, pt. 7, p. 228.

segment. A white line down center of thorax and abdomen to the band on fourth segment. Legs black.

Molts four times previous to pupation.

Full-grown larva shining black with the following markings: A thin line on anterior margin of prothorax and an inverted V-shaped wedge on posterior margin medially; on mesothorax laterally and an inverted V-shaped marking medially reaching anterior margin, same on metathorax, white; orange spot laterally on first abdominal segment and orange band on fourth abdominal segment; median and four lateral longitudinal lines traversing the entire abdomen, white, as also the hind margin of segments 7 and 8. Legs strong and conspicuous. Venter fuscous. 8.5 mm. long.

Pupa like that of *C. inequalis*.

	Days.
Egg stage	3 to 4
Larval stage	15 to 21
Pupal stage	7

Platyomus lividigaster.—The name Pseudoplatyomus is suggested for Platyomus, which is preoccupied in Rhyncophora.

Eggs elongate oval, very small, 0.75 by 0.35 mm., yellowish to brownish, laid in numbers (15 to 20 or more) on their sides on surface of leaf.

Larva when hatched 0.75 to 1.5 mm. long, yellowish brown, with a longitudinal row of fuscous tubercles on either side near margin. Legs fuscous.

Four molts previous to pupation.

Full-grown larva 5 mm. long, reddish brown with longitudinal rows of tubercles as in immature larva. Head fuscous, tubercles white at apex, fuscous at base and surrounded with black on meso- and metathorax and abdominal segments 5 to 9. Legs blackish. Waxy secretion ventrally on thorax and first four abdominal segments.

Pupa reddish yellow mixed with black. Length 3.5 mm., width 2.5 mm., depth 2 mm. Attached by posterior end. Ventrally flat, dorsally convex and carinated. A faint median and two more pronounced lateral longitudinal carinæ. Three conspicuous spines immediately in front of middle, almost entirely covered with white waxy secretion. In pupating the larva rotates its body around the point of attachment, at the same time depositing a thin film of white waxy secretion.

	Days.
Egg stage	3 to 4
Larval stage	7
Pupal stage	5 to 6

Scymnus notescens.—Eggs flat, 0.63 by 0.41 mm., oval or irregular in outline, slightly convex above, ochraceous, finely punctured. Many eggs laid singly on leaf or stem.

Larva when hatched 0.75 mm. long, elongate oval, rather flat, sordid white to greenish black, a black protuberance bearing two hairs laterally on each segment, forming a marginal fringe. Head black, truncate, two large black bars on first thoracic segment, remaining thoracic segments white. Indistinct dark spots and dark line to fourth abdominal segment. Whitish capitate hairs in longitudinal lines on dorsum, four on either side.

Full grown larva 3.5 mm. long, nearly 2 mm. wide, long oval, only slightly convex, head small, labelliform and retractile, prothorax distinctly constricted from the rest of the body, flat above and carapace-like, subquadrate, anteriorly and laterally, with a fringe of very fine hairs. Segments of body rather indistinctly marked, a lateral protuberance on meso- and metathorax and abdominal segments 1 to 8, forming a fringe, each protuberance bearing fine white setæ. Anal segment with caudal fringe of fine white hairs, fine hairs on each side. A transverse line of small white setæ and many scattered hairs on each segment behind head. Color yellowish brown, with a median and two lateral lines fuscous to dark brown, the head and legs outwardly also fuscous to dark brown, basally yellowish, a pale yellow spot on mesothorax and one on anterior margin of metathorax, the prothoracic shield with a median light line separating darker areas, pale again on lateral margin. Lateral protuberances almost black, ultimate segment with median black spot. Venter yellowish brown.

Pupa oval, more or less truncate anteriorly and posteriorly and quite convex. Attached caudally. Head beneath prothoracic carapace forming anterior end of body, wing covers reaching beyond second abdominal segment, laterally to fourth abdominal segment, tips reaching posterior margin. Body covered with whitish hairs. A median longitudinal carina on abdomen dorsally brownish, the prothoracic carapace and last abdominal segment blackish, a median light yellow line on metathorax and abdominal segments. Legs black.

	Days.
Egg stage	1 to 2
Larval stage	10
Pupal stage	5

MEDITERRANEAN FRUIT FLY.

The predictions made in regard to the harmful nature of this fly have been fully justified by the experience of the past year. With optimum conditions for its development and practically no natural checks, the fly has increased with astonishing rapidity, and with the clandestine movement of fruit from one island to another, has spread to and become firmly established in all the principal islands of the group. The fly has shown a wide range of adaptability to different

kinds of fruits, and from the six or seven fruits mentioned in the last annual report as attacked by this pest the list of infested fruits has swollen to the extent of including nearly every fruit with soft pulp in the islands. With many of these fruits, however, the infestation is largely incidental, and there is an undoubted preference shown for peaches, coffee berries, citrus fruits, and kamani seeds.

Little has been actually accomplished in the way of controlling the fly and little can be done under the peculiar conditions existing here, with large areas of uncultivated land and forest supporting a wild growth of fruit-bearing trees, shrubs, and herbs in which the fly can maintain itself in spite of all efforts at artificial control. In circumscribed areas, where the protection of valuable edible fruits made it seem desirable to attempt its control, the commonly recognized methods, such as destruction of infested fruit, spraying, or poisoned bait, and trapping with kerosene, have been tried with fair success. By these methods the fly is reduced to a minimum during the winter months, but with the approach of summer and the appearance of the heavy fruit crops the expense of an adequate control becomes almost prohibitive and the work is surrounded by many almost insurmountable difficulties.

The spread of the fly to the Kona coffee fields for a time produced alarm, but it has not yet been demonstrated that the fly affects the coffee bean in any way or causes any great loss in connection with the crop. The dropping of immature berries, which has been partly ascribed to the fly, is a usual occurrence and may be due to several causes. The fly's part in it is obscured by the phenomenally large crop of the present year.

MISCELLANEOUS WORK.

Some attention has been given to beekeeping and certain aspects of the industry are being carefully studied. During the year two papers on insects have been prepared for publication, one on the insects attacking the avocado in Hawaii, the other on the insects attacking the pineapple.

REPORT OF THE HORTICULTURIST.

By J. Edgar Higgins.

The work of the horticultural department has proceeded along about the same lines as were indicated in the last annual report. The subjects which have received chief attention have been the avocado, the mango, the pineapple, and the papaya. Quite a number of noteworthy varieties of hibiscus have been originated by Mr. Valentine S. Holt, assistant in horticulture. Some attention has also been given to a number of miscellaneous subjects, as the treatment of bananas for shipping, a special method for pruning the peach in this climate, a brief survey of some of the results of onion growing on Kauai, together with assistance rendered at the Homestead substation on Kauai.

In addition to these lines of experiment and investigation, there has been a much larger amount than usual of construction work in progress. Under the immediate supervision of Mr. C. J. Hunn, assistant horticulturist, there have been erected a new insect-proof glass house, a shade house and potting shed, and a workshop and storeroom for horticultural purposes is just being completed. These buildings, together with several new insect-proof tables, add greatly to the equipment.

THE PINEAPPLE.

The most important present horticultural pursuit in Hawaii is pineapple growing. This industry has grown in a little more than a decade from an insignificant position in the activities of the Territory to a place second only to sugar production. The pack of canned pineapples for the present season is estimated at about 1,000,000 cases, valued at $3,000,000. The Hawaiian pineapple has gained a reputation in American markets in the form of fresh fruit and in the can. The canned product has found even a wider field and is being shipped to Europe and other foreign countries. The large demand has stimulated further plantings, and new companies or those already in the business have acquired leases during the year on several thousand acres of land not heretofore under cultivation. The Territorial government has opened for homesteading several tracts of land supposed to be well adapted to the pineapple, and these also will probably be planted chiefly to this crop. Indeed, it seems not

improbable that the present output may be again doubled in the next few years.

How long the demand will keep ahead of the supply and to what extent the Hawaiian trade will be affected by the increasing output of Porto Rico, Cuba, or the Philippines are problems which some of the growers are studying. At present there is no slackening in the demand.

This extension of the pineapple area in Hawaii, and in particular on homestead lands, has given rise to a demand for information relative to the growing of the crop. This station has published from time to time several bulletins on specific phases of the subject, including problems connected with soils, insect pests, diseases, and the marketing of the fresh fruit. Nevertheless, many phases of the subject concerning which inquiry is frequently being made had not been touched upon in these publications, and an attempt has been made to meet this demand in part by a general bulletin from the horticultural division of the station on "The Pineapple in Hawaii." This bulletin [1] includes the results of a few recent investigations as well as a general statement of methods in practice in pineapple growing.

THE AVOCADO.

PROPAGATION.

The experimental work in the propagation of the avocado during the year has been concerned chiefly with the use of quite young seedlings. These have been used both as budding stock and for inarching. (Pl. II, fig. 2, B and C.)

For budding, the stocks have been grown either in nursery row or in containers, such as soy tubs, shingle boxes, ordinary earthen pots, and tin cans. The seeds may be germinated in these or in "ti" leaf pots.[2] Soy tubs from which the salt has been thoroughly washed are satisfactory for a few plants, particularly if they are to remain for some time without transplanting, but the tubs are entirely too large to be economical of space, soil, or transportation costs. They can be bought in quantity for 10 to 12 cents each. Boxes 6 to 8 inches square and about 10 inches high can be made of shingles at a cost of approximately 10 cents each, and these are large enough to carry the plants through until the buds are well established. An ordinary earthen flowerpot serves the purpose well but is more expensive, and if the plant is removed from it and packed for shipping there is greater danger of injury than in the case of a young tree in the container in which it has been grown. One-gallon round tin cans appear to be quite satisfactory. There are usually many of

[1] Hawaii Sta. Press Bul. 36.

[2] Hawaii Sta. Bul. 25, p. 13.

FIG. 1.—HIBISCUS, VARIETY RUTH WILCOX.

FIG. 2.—A YOUNG SEEDLING MANGO INARCHED; B, YOUNG SEEDLING AVOCADO INARCHED; C, YOUNG SEEDLING AVOCADO BUDDED.

these, more or less defective or damaged, that have been discarded at the pineapple canneries. If a cut is made with a can opener, nearly encircling the bottom, drainage is provided and the tree can be shipped in the can. Even when transplanting it is not necessary to take it out, since the bottom of the can may be bent back, affording an opportunity for the roots to get out. It is, however, an easy matter to cut the can on one side when the tree is in place and plant it without disturbing the root system in any way.

If placed in the nursery, the young plants should be about 18 inches apart in rows wide enough to permit of such implements of tillage as it is intended to use. Whether in pots or in the nursery, it is necessary to keep the seedlings in a healthy, rapidly growing condition. They may be budded when they are about five-sixteenths of an inch in diameter and will be ready for planting in garden or orchard in about a year from the germination of the seed.

Another means of shortening the time required in propagation has been the inarching of very young seedlings. For this purpose the seedlings are cared for in the usual way and when about five-sixteenths of an inch in diameter are transplanted to pots or boxes, placing the stem to one side rather than in the center so as to facilitate getting it into contact with the scion. A very convenient substitute for a pot has been suggested by Oliver.[1] This consists of a burlap wrapping. Burlap is cut in strips of suitable size to hold the plants and on this is placed a mixture of soil, sand, and sphagnum moss. The ball of soil surrounding the roots is placed upon this and the whole is wrapped and tied. The advantages of this device are that it is light, compact, and less clumsy than a pot and if necessary can be tied to a branch of the tree, thus eliminating the benches required to support pots. But even if the bench is used, as sometimes seems desirable, a great many more plants can be placed upon it in wrappings than in pots.

The inarching process for these very young seedlings is precisely the same as that for older plants and need not be further described here. It has been found advantageous to fertilize the seedlings about once in two weeks by the use of a small amount of fertilizer added to the water. In the case of avocados a union is effected in about six weeks.

Thus the avocado, which a few years ago was thought to be difficult or almost impossible of asexual propagation, is yielding to many methods of multiplication.

DISTRIBUTION.

By means of these experiments the station has at the same time been perpetuating a number of valuable varieties, some of which have been represented by a single specimen only and otherwise

[1] U. S. Dept. Agr., Bur. Plant Indus. Bul. 202, p. 16.

likely to become extinct. As there is no nursery in Hawaii where grafted or budded avocados can be secured, these plants are being distributed, a small charge being made for them.

One of the varieties which are now being sent out is of seedling origin and of the Guatemala type. It has been grown at the station and is worthy of being named, described, and distributed. This variety, which has been named the Nutmeg, is superior in some respects to its parent and has been described by Mr. C. J. Hunn, as follows:

The Nutmeg avocado. Fruit from the original avocado tree of the Guatemala or "hardshelled" type [1] was collected in December, 1907. A seedling grown from this seed was placed in the orchard on March 17, 1908. This tree came into bearing in December, 1911, four years from seed.

Form roundish to spherical, size medium; cavity small, shallow, and flaring; stem short and inclined to be thick; surface undulating, very hard; coriaceous and markedly pitted; color greenish purple to black with very abundant, irregular-shaped yellowish dots; apex a mere dot, slightly depressed; skin very thick and woody, separating fairly well from the pulp; flesh yellow in color, running into green at the skin; fine-grained, a trifle juicy, oily and somewhat buttery, 68 per cent of the fruit; seed large, roundish, flattened at the base, fitting tightly in the cavity; flavor rich and nutty. Season late.

This tree is quite vigorous and is pyramidal in shape. Height 15 feet, spread 8 feet. (Hunn.)

DISEASES AND INSECTS.

A new injury resulting from the fungus Glœosporium [2] has been observed. A number of the seedling inarches referred to above were found dying back from the wound made in cutting off the scion or the top of the stock. In the case of the budded seeedlings a similar decay was found, beginning at the wound where the stock was headed back and extending down so low as to cut off the supply of sap from the growing bud. It was suspected that these injuries were due to the fungus just mentioned and specimens were submitted to Mr. L. D. Larsen, of the Hawaiian Sugar Planters' Experiment Station, who reported the fungus present in each case examined. It has not been determined whether the infection is frequently made with the knife or merely results from exposure to the spores carried by the wind. In any case it seems best to protect the wounds with grafting wax or with some antiseptic covering. If it should appear that the knife is a potent factor in carrying the disease it may be best to disinfect the blade when using suspicious bud wood.

The wood-boring beetle, *Xyleborus immaturus*,[2] made its appearance in the station orchard during the year and has been much complained of in other parts of the city. This has been combated

[1] Hawaii Sta. Rpt. 1910, p. 28, No. 149; Bul. 25, p. 43.
[2] Hawaii Sta. Bul. 25, p. 23.

at the station by pruning and by the use of a wash composed of 1 gallon soft soap, 3 gallons water, and ½ pint crude carbolic acid. This was applied to the trunks and branches of all the trees with a whitewash brush. The treatment appears to have held the insects in check.

THE MANGO.

The grafting of very young seedlings of the mango has been tested along the same lines as practiced with the avocado and with equally good results. (Pl. II, fig. 2, A.) The mangoes are better to be a little older than the avocado because they do not so quickly acquire the desired diameter of stem and because most of the shoots of the mango trees which are to be used as scions are of considerable size. It has also been found necessary to allow the mango inarches eight or nine weeks to unite, this being at least two weeks longer than the avocado requires. The mangoes that have been thus propagated are chiefly of the Indian and other varieties introduced in recent years but include also some choice kinds that have originated here.

Distributions of these grafted mangoes are being made as indicated for the avocado. The varieties being thus distributed are as follows: Alphonse, Pirie, Oahu, and Smith.

Some interesting results are now available showing the time required for the bearing of budded mangoes. An old tree partly top-worked to the variety Pirie, in February, 1910, is bearing this year some fruit which will mature in about two and one-half years from budding. The varieties Smith and Java are requiring about two and one-fourth years and the Gay a little more than three years. The latter, however, was budded very late in the season (May 24) and did not have the advantage of the best season of growth, which is from December to May. These results would suggest that trees budded in December or January may be expected to produce some fruit in about two years from the following June and July, these months being the mango fruiting season.

There are fruiting at the station this summer, but not mature enough for describing at the date of this writing, the following varieties: Brindabani, Totafari, Gay, Java, Wootten, Bennett Alphonse, Alphonse, Divine, Pirie, and Smith.

The mango is being very seriously attacked by the Mediterranean fruit fly, *Ceratitis capitata*, and it has been necessary to cover with cotton bags the fruits of many of the varieties. Although several fruits can be placed within one bag, the practice is tedious and expensive. Nevertheless, it is well worth the trouble in the case of the best varieties. Fortunately, not all varieties are equally susceptible, some being quite resistant. It can not be stated that there are any which are immune from the attacks of this fly, but no

infestation has yet been found on the Brindabani, although the fruits are not ripe at this time and may be attacked later. The Smith and several of the Cambodiana type, locally known as "Chutney" varieties, appear to be attacked only slightly, and chiefly when the fruit is very ripe. By picking the mangoes of these kinds before they have begun to soften the fly can be avoided to a considerable degree. Too much confidence should not be placed in these habits, for there are many other varieties upon which the maggots may feed, and if these were not in fruit the flies might deposit more eggs in the fruits which now show resistant qualities.

THE PAPAYA.

The papaya investigations have been continued along the lines indicated in the last two annual reports. There is little to report in the way of new conclusions, but some interesting data are developing. One of the questions which have naturally arisen in this study has been whether the monœcious or the diœcious type is the more primitive, and, further, as to the origin of the later type. There are now under observation a series of gradations between the two types which appear to indicate that the monœcious papaya has developed from the staminate tree of the diœcious type. It was stated in earlier reports that this staminate tree occasionally produces a perfect flower which matures a fruit.[1] There are now trees at this station bearing none, others bearing only a few, and still others producing no less fruits than many pistillate trees. One has 87 fruits upon it at this writing. These fruits and the flowers that produce them are of the general form of the monœcious type. If, then, the long peduncle upon which they are born be shortened, the result would be the ordinary monœcious papaya. A tree has been under observation in which these peduncles are midway in length between those of the monœcious tree and those of the so-called "staminate" tree which produces fruit. The observer might be in doubt whether to call this tree one of the monœcious type with extra long peduncles or a "staminate" tree producing an extraordinary number of fruits, for these differ apparently only in the number of the fruits and the length of the peduncles. There is also under observation a staminate tree with flower stems as short as those of any pistillate tree. Some of the gradations referred to are illustrated in Plates III and IV.

But even if this series of gradations approaches completeness sufficiently to justify the conclusion that there has been an evolution from the one type to the other, the further question arises, Are we justified in concluding that the process has been in the direction sug-

[1] All staminate flowers of these trees have aborted pistils, but, with the exceptions mentioned, they do not possess a stigma, and can not produce fruit.

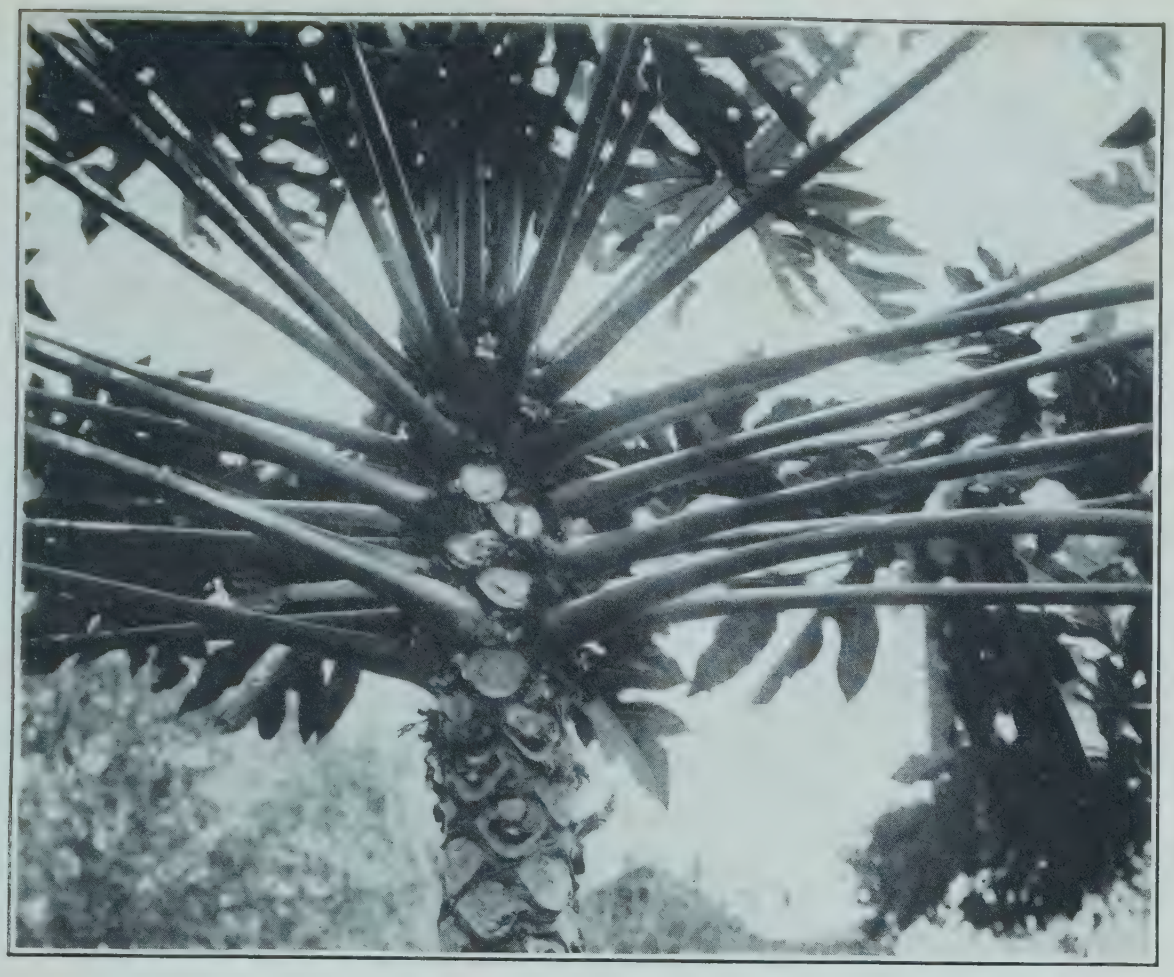


FIG. 1.—A STAMINATE PAPAYA TREE WITH VERY SHORT FLOWER STEMS.

FIG. 2.—A STAMINATE PAPAYA TREE BEARING NO FRUITS.

FIG. 1.—STAMINATE PAPAYA TREE BEARING ONLY TWO OR THREE FRUITS.

FIG. 2.—STAMINATE PAPAYA TREE BEARING MANY FRUITS.

gested and not the reverse—viz, from monœcious to diœcious? Proceeding temporarily upon the supposition that the monœcious type was the earlier form, it may be imagined that the peduncles became lengthened and the number of staminate flowers increased and the perfect flowers decreased until the evolution had arrived at a regular nonfruit-bearing staminate tree. But this would not account for the pistillate tree, which is the necessary counterpart of the staminate. To account for this, supposing the evolution to have proceeded in the direction hypothecated, it would be necessary that a pistillate flower of entirely new form be evolved from the perfect flower. All of this appears less probable than the suggestion that the diœcious type was the more primitive and gave rise to the monœcious.

In this connection it may be well to record a recent experience in planting. Papaya seeds were received from the United States Department of Agriculture, Office of Seed and Plant Introduction,[1] and planted under our accession number 1996. Sixty seedlings were set out in orchard form. Of these, 33 proved to be pure pistillate trees and 27 were staminate, a few of the latter producing an occasional fruit. One of these fruits was selected and its seeds planted. Of these, 16 trees were planted, and 4 of these are normal pistillate and 12 are staminate. But of the staminate trees 9 are bearing fruit and some of them in large numbers, such as 21, 37, and 87 fruits per tree. This may have some bearing upon the question which has been under discussion. In any event, the facts are of sufficient interest to record.

The work of breeding toward a reasonably stable variety of desired characters by means of cross pollination, close pollination, and selection is being carried on, and some excellent trees are being studied.

BANANA SHIPPING.

The shipping of bananas from Hawaii to the mainland has undergone some changes during the year. The spreading of the Mediterranean fruit fly in different islands of the group has led to increasing vigilance and greater caution on the part of California. It was thought that the banana leaves, in which the fruit has always been wrapped, were not a very safe packing. It was therefore directed by the California authorities that banana leaves must not be used, but that rice straw would be an acceptable material for the purpose. After a few shipments it was learned that the rice straw injured the rind of the fruit, causing it to become black. Then followed the testing of a paper wrapping inside of the rice straw and also of a cheesecloth wrapping. Each of these is reported to have afforded considerable protection, and one or the other is now in general use. Scale

[1] S. P. I. No. 23915.

insects and mealy bugs of several species have also made it necessary to guard carefully incoming bananas at San Francisco. Because of these various difficulties some experiments were made in fumigating bananas with hydrocyanic-acid gas. Six bunches of bananas were secured on March 23 and held in the fruit room until March 29. Two bunches were then treated with 1½ ounces cyanid in 260 cubic feet for 45 minutes. Two others were given 2 ounces of cyanid for 45 minutes, and the remaining two were held as a check without treatment. The wrapping had been removed from all before treatment. Repeated examination of all these daily until ripe revealed no indication of any injury to the fumigated fruits.

Again on April 3 a plantation was visited and six bunches were selected which were infested with the following scale insects and mealy bugs: Florida red scale (*Chrysomphalus aonidum*), the white-wash scale (*Hemichionaspis minor*), and a mealy bug (*Pseudococcus* sp.). These bunches were wrapped at once in banana leaves and taken to the experiment station, where they were held for two days. They were labeled 7, 8, 9, 10, 11, and 12, and treated on April 5 as indicated below:

No. 7. Not wrapped, not fumigated (check).

No. 8. Wrapped, not fumigated (check).

No. 9. Not wrapped, 1½ ounces cyanid in 260 cubic feet for 45 minutes.

No. 10. Wrapped, 1½ ounces cyanid in 260 cubic feet for 45 minutes.

No. 11. Not wrapped, 2½ ounces cyanid in 260 cubic feet for 60 minutes.

No. 12. Wrapped, 2½ ounces cyanid in 260 cubic feet for 60 minutes.

The fruits were carefully examined by the station entomologist after treatment, but in no case was a living insect found upon the fumigated bunches whether bare or within the wrapping. All were kept until fully ripe, which in the case of some bunches was over three weeks, and during this time careful observations were made by several members of the staff to discover any injury that might have been done to the fruit in fumigating. No difference could be detected between the fumigated and unfumigated fruit in appearance, texture, or flavor. It has been reported that injury has resulted from the treatment of bananas with this gas in San Francisco. It seems not improbable that this may have been the case, for bananas coming from a ship after a six-day voyage are liable to be moist, and it is a well-known fact that hydrocyanic-acid gas is injurious to tender plant tissues when they are wet. But from the experiments recorded above it is reasonable to conclude that if fumigation is neces-

sary it may be practiced here before shipping without injury to the fruit and with deadly effect upon the insects.

HIBISCUS.

The hibiscus is now receiving much public interest and more requests have been received for cuttings of these plants than for any other. Over 25,000 cuttings have been distributed. Mr. Holt, who has charge of the hibiscus work, states that he now has over 200 new varieties under observation. Some of these are of great beauty and will add much to the floral wealth not only of Hawaii but of other parts of the Tropics and Subtropics. One of the most attractive of the new sorts is shown in Plate II, fig. 1. Mr. Holt has named this the Ruth Wilcox. A half tone can not do justice to such a flower, but reveals the free-flowering habit and good form of shrub. This is one of the few hibiscuses which emit a delicate perfume.

CITRUS.

The orchards of citrus which have been budded to many varieties are now coming into bearing. In the report of the assistant horticulturist will be found a list of the varieties which are fruiting.[1]

Bud wood of a number of these varieties has been distributed to various parts of the Territory and about 320 stocks in the station nurseries have been budded to some of the most promising.

The records of two trees budded to Kusaie lime in May, 1908, are worthy of note. They began fruiting in the fall of 1909 and have been in bearing almost constantly since that time. A record was kept of the yields in 1911, showing 467 fruits weighing 40½ pounds from one of these trees and from the other 419 fruits weighing 39½ pounds.

MISCELLANEOUS EXPERIMENTS AND OBSERVATIONS.

The horticulturist made a short trip to the island of Kauai in September to render some assistance to the Homestead substation and arrange for some trials in onion growing. Seeds of a large number of varieties of onions including some of the Bermuda type were later sent to Kauai and were planted at the substation at Homestead and in several other parts of the island.

At that time it had been rumored that the Mediterranean fruit fly had appeared at Makaweli. A brief investigation proved this to be the case and on August 28, immediately after the adult insects had been bred from the material collected on Kauai, the information was communicated to the Commissioner of Agriculture and Forestry. In May another visit was made to Kauai to review the onion tests

[1] See page 48.

mentioned above, to give some instructions in propagation at the substation, and to study the pineapple industry on that island. The last two subjects have been noted earlier in this report or in a press bulletin of the station on The Pineapple in Hawaii[1] and need not be further reported upon here. Some mention should be made of the results of the onion tests. The marketing division of the Territorial government had also distributed some very good seeds of the Bermuda type. Onions were found growing in many places from Waimea to Hanalei and in soils varying from heavy clay to light coral sand mixed with a small amount of humus. In general it may be stated that first-class marketable onions were found in many soils and at elevations ranging from sea level to 600 or 700 feet, which appeared to be about as high as they had been tried. On all the heavier soils, however, a serious disease was prevalent which appeared to be identical with the bacterial disease of this crop known as "center rot" or "slippery onions."[2] This disease may attack the top of the bulb and progress into the center, giving rise to the first of the names applied to it, or it may affect the outer scales causing them to decay and the onion to be very slippery, which has given rise to the second of the common names. The malady is one which prevails chiefly in heavy soils and in damp climates. Very little of it was found on the low sandy soils of Kauai, lying near the beach and supplied with moisture chiefly from beneath. In several places it was found that free water exists only a few feet below the surface of the soil and is conducted to the plants by capillarity. There is a considerable area of sandy and loamy soil on Kauai which appears to be adaptable to this crop, but as there is no effective remedy for the bacterial disease referred to, cultivation on the heavier soils should not be attempted without caution.

In closing it is desired to express appreciation of the very faithful services of Mr. C. J. Hunn, assistant horticulturist, and of Mr. Valentine S. Holt, assistant in horticulture.

[1] Hawaii Sta. Press Bul. 36.

[2] New York State Sta. Bul. 164; Georgia Sta. Rpt. 1900, p. 355.

FIG. 1.—PANORAMA OF BUILDINGS.

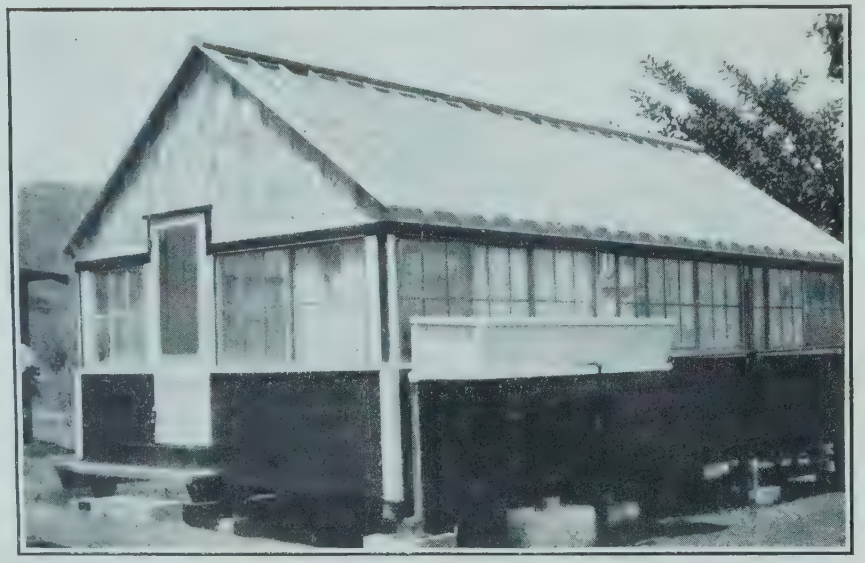


FIG. 2.—GLASS HOUSE.

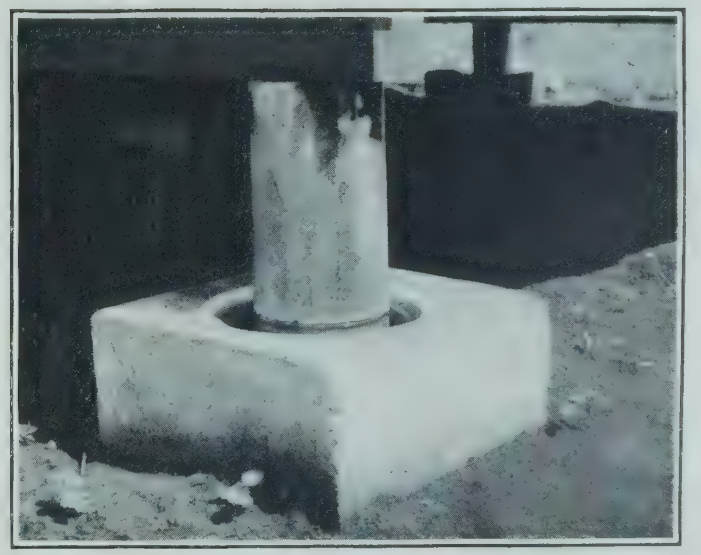


FIG. 3.—CEMENT PIER.

GENERAL VIEW OF HORTICULTURAL BUILDINGS.

REPORT OF THE ASSISTANT HORTICULTURIST.

By Chester J. Hunn.

BUILDINGS.

The year has been essentially one of reconstruction and building up. While passing through the transitional period between the discarding of the old and the actual construction of the new buildings (Plate V) six outside ant-proof benches [1] were erected.

A shade house supported by concrete pillars was the first building constructed. The slats in the old shade house showed a tendency to warp in all directions and to throw into the house the water that should be drained away. The adaptability of two grooves, one on either side and three-quarters of an inch from the edge of the upper surface of the slat, is now being tested. The opinion is that when the slats warp they will turn upward and form a trough which will insure better drainage.

Adjoining the shade houses is a potting room. It has a rock floor covered with a sloping concrete surface. In this room are a spacious potting bench, reinforced concrete bins for soil and sand, pot racks, and a packing table.

The necessity of a glass house for propagating purposes has been very apparent. It should be proof against insects, birds, and rodents, for the former shade houses were faulty in this respect. The regulation of temperature and air currents has also not been within the control of the propagator.

A glass house which should fulfill these conditions is practically finished, detailed plans of which are given herewith (fig. 1). All the supports and the piping are ant proof. Wooden doors near the floor, sliding glass sash on the sides, and ventilators in the roof control the ventilation of the house. All openings are covered with bronze mosquito wire. The intensity of the sun's rays will be regulated by whitewashing the glass and by the use of curtains.

The interior arrangement of the house affords means for several methods of plant propagation. The center bench is zinc lined for subirrigation purposes, especially for delicate seeds which do not permit of surface watering. At one end is a glass box for seeds requiring a high temperature in which the amount of humidity can be controlled.

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[1] Hawaii Sta. Rpt. 1911, p. 42.

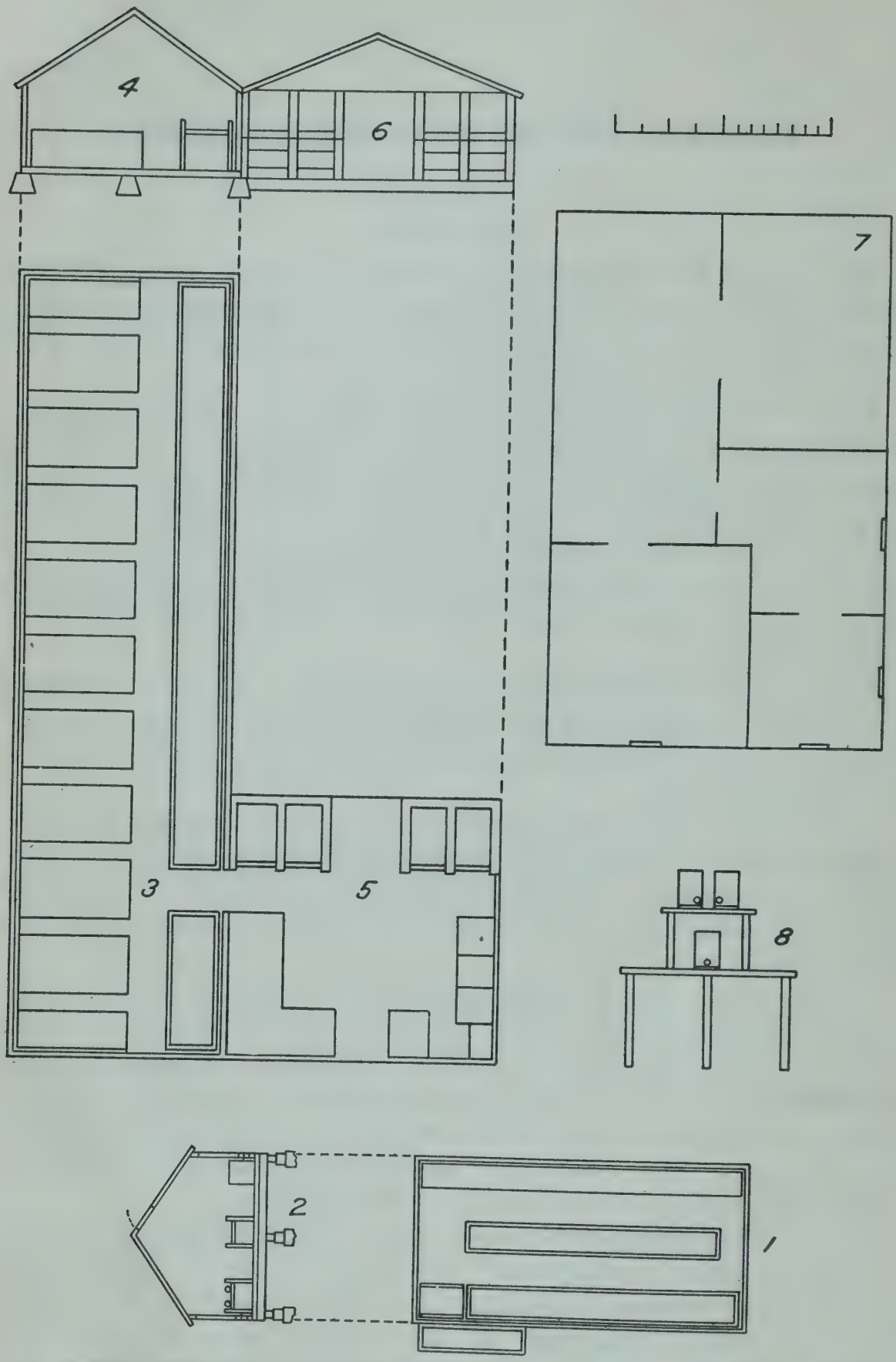

FIG. 1.—Details of horticultural buildings: 1 and 2, interior bench and elevation plans of glass house; 3 and 4, same of shade house; 5 and 6, same of potting house; 7, interior plan of work house; 8, elevation plan of spray stand. (Scale 16 feet to 1 inch.)

Experience in propagation by cuttings in the Tropics leads to the belief that bottom heat is necessary to the best success. Temperature readings in a thickness of 6 inches of moist sand show that the surface temperature is 6° higher than the bottom temperature. Cuttings should callus and root before the leaves reach a large size, in order to provide a portion of the sustenance for the leaves and to prevent them from using much of the material stored in the tissues of the cuttings. Under prevailing conditions the leaves uniformly appear before the root system has become well established.

Facilities are now at hand for practical work in the bottom-heating problem. Water, heated by the sun's rays in a glass-covered wooden box, is conveyed by pipe through the sand propagating bed. After the heat is dissipated the water is returned to the heater to complete the circulation.

This department has outgrown other appointments. This is being remedied by the construction of a work building divided into a poison room, rat and insect proof seed and fruit rooms, a storage room, and an open work compartment. A modern spray stand has been erected so that all liquids can be conveyed by gravity from the stock solution barrels to the mixing barrel and from hence to the spray barrel on a wagon. A reinforced concrete stove was also constructed. This stove affords a place for the cooking of spray mixtures, the boiling of fruit infested with fruit-fly eggs, and the melting of such material as wax for bandages.

PLANTINGS.

During the past year, the budded orchards have been increased by the successful transplanting of budded citrus and mango trees. Miscellaneous fruit and ornamental trees have been planted in their respective plats. The nurseries have been extended by plantings of citrus, mango, and avocado seedlings.

Cover crops as usual have been drilled into the orchards to hold the soil during the rainy season and to increase the humus content of the soil. The several varieties of cowpeas, pigeon peas, and jack beans that have been received during the year, as well as those varieties which have been segregated from seed collection, have been planted in plats for the production of seed.

SPRAYING.

Since the orchard trees are rapidly assuming mature proportions, it has become apparent that spraying operations could not be performed with the small, barrel spraying outfit. A double-acting cylinder spray pump that can maintain a pressure of 120 pounds or more per square inch has been secured. The outfit is complete with a 50-gallon barrel that has been fitted up with a mechanical agitator.

The avocado and mango orchards were sprayed once last fall.[1] These orchards have been sprayed once this season. The comparative freedom of the orchards from fungus disease shows that spraying is necessary and effective. The combined action of spraying and of the natural enemies has thus far kept the injurious insects well in control.

MAPPING.

One of the important lines of work undertaken this year was the revision of the field maps made in 1909. Some trees had died and many new ones had been placed in the orchards, making this revision imperative. Maps of these fields, by sections, have been bound by series in portfolios so that they are adapted to both field and office work. Every orchard tree has been labeled with a large painted tree label. After writing the number and name, the label was dipped in a thin solution of shellac, which insures its durability for some years.

A résumé of the maps shows that, excluding the Tantalus plantings, the hibiscus, and the windbreaks, we have the following trees:

Small citrus seedlings	1,436	Small avocado seedlings	308
Large citrus seedlings	191	Large seedling avocados	181
Budded citrus	184	Large budded avocados	15
Small mango seedlings	705	Large inarched avocados	7
Large mango seedlings	263	Small inarched avocados	5
Large budded mangoes	25	Figs	70
Large inarched mangoes	35	Papaya	490
Small inarched mangoes	20	Miscellaneous fruits	425
Ornamental trees	597	Ornamental shrubs	596

The budding work on the citrus seedlings has proceeded as in former years. This budding has not only required skill in placing the buds, but has demanded much attention in irrigation and in protection against ants, aphis, and scale insects.

The following varieties of budded citrus are now bearing fruit:

Oranges: Dancy, Golden Buckeye Navel, Mediterranean Sweet, Navelencia, Paper Rind, St. Michael, Ruby Blood, Satsuma, Thompson Improved Navel, Valencia Late, and Washington Navel.

Pomelos: Duncan, Marsh Seedless (California), Marsh Seedless (Florida), and Triumph.

Lemons: Eureka and Villa Franca.

Limes: Kusaie, Seedless, and Tahiti.

Miscellaneous: King Mandarin, Willow-leafed Mandarin, and citron of commerce.

THRASHING.

The amount of labor necessary to thrash and clean the seeds of legumes to be used for cover crops has become so great that a small power thrasher was secured. This machine can be successfully used

[1] Hawaii Sta. Bul. 25, p. 24.

for pigeon peas and cowpeas. Although it will thrash the jack bean, the beans have to be separated by hand from the refuse.

ACCESSIONS.

This department is continually receiving seeds and plants from various parts of the world. These are planted and, if subsequent testing proves their worth, the increase is distributed. Others of known value are immediately distributed. Among the accessions of the past year are a collection of passiflora plants and papaya seed from the Office of Seed and Plant Introduction; seeds of papaya varieties from the West Indian Islands, Central America, and Bolivia; varieties of roselle from Africa; onion seed from Madeira; and several varieties of cowpeas. The plantings of fiber Musas other than those of the true commercial Manila hemp have been made. Seedling plants of the Philippine variety, Maguindanao, grown at Washington, have been received. The plants which have been grown as *Carissa arduina* have been identified as *C. grandiflora*. Seeds of the true *C. arduina* are now germinating. The varietal collection of avocados has been increased by California, Kona, and Honolulu varieties, the latter being principally of described varieties.

DISTRIBUTIONS.

During the past year this department has filled requests for plants and seeds for many agricultural institutions. The public in general has requested material assistance, which has been granted whenever possible.

Several years ago this department secured seeds of an improved type of the so-called "Easter or Bermuda Lily," a cross between *Lilium longiflorum giganteum* and *L. multiflorum*. The transmission of fungus diseases is prevented by the use of seed. When the bulbs and plants were taken up this year several new plats were started. There is now a large number of plants from "scale" propagation on hand for distribution.

RECORDS.

From the time that accession records have been kept, these records show over 3,000 entries of seeds and plants. Seeds have failed to germinate, plants have not survived the struggle for existence, and others have served their usefulness. With the revision of the field maps came the task of bringing these records up to date. Instead of five chronologically arranged accession books there are now two, which include only live material. The corresponding index cards have been filed. The discarded index cards and the distribution cards have each been filed away for future reference.

MISCELLANEOUS.

At the poultry show practical examples of grafting and budding in all stages of manipulation and growth were shown. The fruits of budded citrus trees, together with the novelties that were in season, were displayed. The results of selection with the papaya were noteworthy. The demonstration of the various stages of practical plant breeding with the hibiscus promises to increase the number of amateur breeders. The exhibit of hibiscus flowers, averaging 200 or more daily, was a signal effort on the part of Mr. Holt.

The avocado trees in the Hilo district appear to be suffering, and a few recovering, from some fungus disease. The results of this attack, unusual rainfall during the blossoming period, the abnormal abundance of lichens, and the lack of judicial pruning have made the fruit scarce and lacking in quality. In the forest area of the "aa" flows which lie between Hilo and Puna are scattered avocado trees just coming into bearing. These trees have grown up from seed scattered by trainmen.

In Puna the avocado trees appear moderately vigorous, although they are planted in a somewhat dry soil. The fruits are reported to be watery, slightly fibrous, and to lack the usual agreeable flavor.

In Kona the avocado is not planted in orchard form, but is grown in dooryards and in and about the borders of coffee plantations where the pockets of soil are of a sufficient size. Kona produces much of the off-season fruit marketed in Honolulu. A few fruits were still in season. The trees with few exceptions are neglected.

REPORT OF THE ASSISTANT CHEMIST.

By William McGeorge.

The chief lines of work which have occupied the attention of the chemical department during the year are as follows: A continuation of investigations upon soil conditions and an accumulation of a large number of analyses of soils with the idea in view of publishing a general survey of Hawaiian soils. Several miscellaneous investigations and analyses have been made, also a chemical study of the sisal leaf and the waste accruing from decortication, and some further studies upon the rice plant, dealing in the main part with the sulphur and chlorin content.

SOILS.

About 150 samples of soil have been examined during the year, a large portion of which were taken in proposed new pineapple land on this island and the Haiku district of Maui. The prime factor in the examination of soils to be used in growing pineapples has been the determination of the manganese content, the deleterious effect of which has been thoroughly dealt with in previous publications of this station. At this point it may be of some interest to state that the highest manganese content of any soil examined from the islands, other than Oahu, has been a sample from Lanai which contained 1.13 per cent. However, comparatively few soils from the other islands have been examined and a more thorough survey during the coming year is contemplated. In the course of this soil work some further attention has been given to the sporadic type of soil mentioned in the last annual report, namely, that of abnormally high titanium content, and some rather important results have been obtained. Samples of this type have been collected from several districts upon this island (Oahu) and one district at Haiku, Maui, which contains 18.84 per cent TiO_2 in the soil and 20.02 per cent in the subsoil at a depth of 30 inches. The soil of highest content contained 34 per cent TiO_2. It is possible that the precipitate of TiO_2 contained other of the rarer metals in small quantities. However, it was free from iron and aluminum. It was not deemed worth while at this time to attempt a separation of the rarer metals, but it may possibly be done later. These soils are of a vastly different type, both chemically and physically, from any of the other soils found in Hawaii heretofore. The normal Hawaiian soils contain about 5 per cent TiO_2. Apparently the titanium is the most insoluble constituent

of the Hawaiian soils. These titanium soils contain a strikingly smaller content of aluminum and a higher content of ferrous iron, which probably imparts to them the characteristic blue or gray color.

LYSIMETER EXPERIMENTS.

The application of lime to the soils of the Wahiawa district on this island has failed to produce any visible improvement in their tilth. However, this is not surprising, in view of the fact that the Hawaiian clays are of a very different character from those of other countries. In view of the above fact a set of lysimeter experiments was started to observe the effect, both chemical and physical, of lime. The chief reason for the application of lime as fertilizer is to correct soil acidity and to supply a basic element to combine with the organic acids formed in the decomposition of organic matter, thus maintaining the neutrality of the soil. Also it acts indirectly as a source of plant food, by rendering available small quantities of mineral matter, particularly phosphoric acid and potash. Mechanically it has the property of causing a flocculation of clay, so that when the soil becomes wet and is subsequently dried the lime acts as a cement, holding the particles of clay together in larger aggregates.

The four soils selected for use in these experiments were of very different types. No. 1 was a heavy clay soil from the Wahiawa district, No. 2 a soil of "intermediate" manganese content, No. 3 a heavy clay soil in badly puddled condition, and No. 4 a highly manganiferous soil. Twelve lysimeters were used, three for each type of soil, one of which was used as a check. To the second carbonate of lime was added and to the third sulphate of lime. Twenty-five pounds of air-dried soil were used in each lysimeter, and the lime added in such quantity as to make an addition of 0.1 per cent of CaO. In each instance the lime was thoroughly mixed with the soil and a small quantity of water added, to dampen the whole before placing in the lysimeter. The following chemical and mechanical analyses show the types of soil used:

Chemical analyses of soils.[1]

Constituents.	No. 1.	No. 2.	No. 3.	No. 4.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Titanic oxid (TiO_2)	2.25	0.03	0.50	0.68
Insoluble matter	39.26	40.66	38.22	31.67
Ferric oxid (Fe_2O_3)	24.33	14.99	27.89	18.60
Alumina (Al_2O_3)	14.65	19.71	13.86	14.67
Manganese oxid (Mn_3O_4)	.21	2.40	.10	9.21
Lime (CaO)	.50	.10	.05	1.32
Magnesia (MgO)	.36	.47	.80	.52
Potash (K_2O)	.49	.45	.34	.79
Soda (Na_2O)	.20	.22	.32	.38
Phosphoric acid (P_2O_5)	.06	.24	.14	.20
Sulphur trioxid (SO_3)	.08	.23	.17	.15
Volatile matter	13.65	15.75	12.17	16.78
Moisture	3.98	5.15	5.66	5.36
Total nitrogen	.32	.30	.31	.37

[1] Analyses made according to official method.

Mechanical analyses of soils.[1]

	No. 1.	No. 2.	No. 3.	No. 4.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Soluble in dilute HCl	2.07	.....	.....	2.71
Moisture	3.51	5.15	5.66	5.46
Organic and volatile matter	12.68	15.75	12.17	15.86
Fine gravel	.00	.04	.....	.82
Coarse sand	.75	1.53	.45	7.74
Fine sand	3.51	8.49	3.47	21.22
Silt	8.54	8.60	5.67	13.18
Fine silt	33.33	29.75	42.85	21.87
Clay	35.01	30.57	29.94	12.40

[1] Analyses made according to Hall, The Soil. London, 1908, 2. ed., p. 51.

The experiments were started on April 13, 1911, and water was added from time to time to replace that lost by evaporation. After eight months samples were taken from each of the lysimeters for analysis, to determine the water soluble and 1 per cent citric acid soluble constituents, this being deemed a better means of working on the soils than by treating the soil with water in the lysimeters and collecting the percolations for analysis. In the analysis 100 grams of soil were placed in a glass bottle and extracted with 1 liter of water, at room temperature, with occasional agitation, for one week. For citric acid soluble matter 100 grams were extracted, with 1 per cent citric acid solution for the same length of time. The results of the analyses are as follows:

Water soluble constituents in parts per million.

Soil No.	Lime added.	Lysimeter No.	Al_2O_3 Fe_2O_3.	Mn_3O_4.	CaO.	MgO.	Na_2O.	K_2O.	SO_3.	P_2O_5.
.....	Check.....	1	18	7	53	16	39	49	39	13
1.....	$CaCO_3$.....	2	11	6	91	12	54	89	47	5
1.....	$CaSO_4$.....	3	17	22	531	28	51	62	248	8
2.....	Check.....	4	11	9	53	14	40	55	30	40
2.....	$CaCO_3$.....	5	12	7	143	11	59	56	52	14
2.....	$CaSO_4$.....	6	9	37	554	48	47	91	270	16
3.....	Check.....	7	21	7	74	16	65	69	27	30
3.....	$CaCO_3$.....	8	5	9	151	18	60	74	46	38
3.....	$CaSO_4$.....	9	5	36	464	39	33	66	268	15
4.....	Check.....	10	9	7	249	40	79	133	65	57
4.....	$CaCO_3$.....	11	9	10	383	47	77	108	83	55
4.....	$CaSO_4$.....	12	3	13	907	69	127	133	407	47

This table does not show any very striking chemical effects resulting from the use of the lime, but at the same time some of the effects are of interest. The usual chemical changes resulting from the addition of lime, namely, an increase in the solubility of the phosphoric acid and potash, were not effected, which, however, may be due to experimental discrepancies. In every instance except one the lime caused a decrease in water soluble phosphoric acid. In the majority of instances it effected an increase in solubility of potash. It is also interesting to note that in every instance the addition of sulphate of

lime produced a marked increase in the solubility of the manganese and magnesium. The water soluble phosphoric acid was determined colorimetrically from a solution obtained by extracting 500 grams of the soil in 1 liter of distilled water.

Citric acid soluble constituents.

Lysimeter No.	Lime added.	Fe_2O_3.	Al_2O_3.	Mn_3O_4.	CaO.	MgO.	K_2O.	Na_2O.	P_2O_5.	SO_3.
		Per ct.	*Per cent.*	*Per cent.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
1	Check	0.136	0.410	0.003	0.030	0.058	0.034	0.034	0.0057	0.050
2	$CaCO_3$	.154	.440	.005	.075	.056	.026	.026	.0051	.054
3	$CaSO_4$	.147	.445	.007	.078	.060	.032	.032	.0077	.112
4	Check	.132	.839	1.484	.050	.088	.052	.052	.0077	.085
5	$CaCO_3$	.129	.839	1.456	.085	.090	.045	.045	.0038	.100
6	$CaSO_4$	.129	.812	1.507	.075	.110	.045	.045	.0025	.195
7	Check	.206	.434	.040	.040	.088	.094	.094	.0077	.064
8	$CaCO_3$	.192	.452	.026	.048	.072	.096	.096	.0051	.100
9	$CaSO_4$	.198	.481	.044	.062	.076	.077	.077	.0045	.140
10	Check	.055	.508	1.907	.110	.140	.130	.130	.0077	.090
11	$CaCO_3$	.055	.496	1.950	.157	.120	.145	.145	.0038	.065
12	$CaSO_4$	.065	.490	1.965	.147	.155	.151	.151	.0083	.185

Apparently, from this table, there is little regularity in the changes effected by lime as regards the citric acid soluble constituents. Phosphoric acid and potash were in some instances decreased, while in others there was an increase. The action of sulphate of lime was similar to that shown in the previous table; that is, it effected an increase in the solubility of the magnesium in every instance except one and an increase in the solubility of the manganese in every instance.

NITRATES AND AMMONIA.

It was also considered to be of sufficient importance to observe the changes in the nitrates and ammonia content at various intervals, produced by the lime, comparing the results with the check lysimeter. The results of these tests are given in the following table:

Variation in nitrates and ammonia in different lysimeters, parts per million.

Soil sample No.	Lysimeter No.	Lime added.	Nitrates.		Ammonia.	
			June 13, 2 months.	Nov. 13, 8 months.	June 13, 2 months.	Nov. 13, 8 months.
1	1	None	7.8	3.5	56.4	56.4
1	2	$CaCO_3$	7.3	6.9	33.6	28.2
1	3	$CaSO_4$	10.4	2.6	33.6	28.2
2	4	None	15.65	8.7	33.66	56.4
2	5	$CaCO_3$	17.85	1.3	39.6	28.2
2	6	$CaSO_4$	13.85	8.3	33.6	28.2
3	7	None	15.65	3.0	16.9	28.2
3	8	$CaCO_3$	25.00	4.4	16.9	42.3
3	9	$CaSO_4$	20.80	2.6	39.6	56.4
4	10	None	41.50	12.8	50.8	56.4
4	11	$CaCO_3$	17.85	10.5	39.6	56.4
4	12	$CaSO_4$	25.00	11.7	56.4	42.3

While the above tests do not duplicate field conditions, they indicate a great variation in nitrogen content and a striking decrease in nitrates upon standing in the lysimeter under normal climatic conditions. These tests also indicate the necessity of further work being carried on along this line before reaching any conclusion as to the effects of the different forms of lime upon the nitrate and ammonia content of these soils.

EFFECT OF LIME ON CAPILLARITY.

The only means the surface soil possesses by which it is able to replace the moisture lost on evaporation is capillarity. Of the several kinds of water existing in soils, the capillary form is probably the most important, for the above reason. It not only serves as a means of supplying moisture to the plant during dry weather, but also as a carrier for plant food. This capillary movement of moisture is caused by surface tension, and it is of some interest to know the effect of lime upon this property of the soil. Accordingly, a set of glass tubes, 2 centimeters in diameter, were fitted up and the rate of capillary rise and downward capillarity determined, with the following results:

Upward capillarity.

Soil sample No.	Time.								
	1 hour.	3 hours.	7 hours.	24 hours.	48 hours.	72 hours.	96 hours.	5 days.	6 days.
	Cm.	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*
1	14.0	19.5	25.0	32.75	.....	41.25	43.5	45.75	47.5
2	14.5	20.5	26.75	35.5	.....	43.75	46.0	48.0	49.5
3	12.75	18.5	24.0	30.25	.....	36.5	38.0	40.0	41.25
4	19.5	24.5	30.0	37.5	42.5	46.0	48.25	50.5	53.5
5	18.5	23.75	29.25	37.0	42.0	44.5	46.5	48.25	50.5
6	16.0	21.5	28.0	36.25	39.75	41.5	42.75	44.0	45.5
7	9.75	14.5	18.25	24.0	.....	30.5	31.75	33.0	34.25
8	9.75	13.25	17.5	23.25	.....	28.5	30.25	31.5	32.25
9	10.5	13.5	17.25	23.25	.....	27.75	29.5	30.75	32.0
10	20.0	26.5	34.5	46.0	52.0	56.0	59.5	61.75	65.25
11	19.0	26.5	33.25	42.5	46.5	49.0	51.0	52.75	55.0
12	19.5	26.5	33.25	43.0	49.25	53.0	56.0	58.0	61.0

In this table the capillary rise is shown to be more rapid where no lime had been added to the soil in every instance except that of soil No. 1, a heavy clay. The sulphate of lime decreases the rate of capillarity in every instance, and in all cases except the last the rate is less than that where carbonate had been used. In these experiments the glass tubes were allowed to stand in water, the end dipping about one-half inch into the water.

Downward capillarity.

Soil sample No.	Time required for disappearance of water below surface.	Penetration of water at time of disappearance from surface.	Final depth.	Soil sample No.	Time required for disappearance of water below surface.	Penetration of water at time of disappearance from surface.	Final depth.
	Hr. min.	*Cm.*	*Cm.*		*Hr. min.*	*Cm.*	*Cm.*
1	3 7	36.0	46.0	7	4 27	34.0	41.0
2	3 4	34.5	44.0	8	6 55	34.0	39.5
3	1 55	34.0	44.0	9	3 28	34.0	42.5
4	1 21	38.0	50.0	10	1 36	31.0	38.5
5	1 49	34.5	45.5	11	1 44	33.5	41.5
6	1 52	34.5	45.5	12	1 54	33.0	40.5

From this table it may be seen that the manganiferous soils, Nos. 2 and 4, are not greatly affected by the addition of lime beyond a slight decrease in the rate of downward movement of the water. The soil containing 2.4 per cent Mn_3O_4 (No. 2) showed a slight decrease in the depth to which the water reached, which indicates an increase in the absorptive power of the soil by use of lime. The highly manganiferous soil (9.2 per cent) showed the opposite effect, namely, an increase in depth to which the water reached and a decrease in absorptive power. A glance at soil No. 1 shows an increase in rate of downward movement of the water and also an increase in the absorptive power as a result of the addition of both forms of lime. But soil No. 3, which contains about 6 per cent less clay, shows a much more striking variation in rate of capillarity, but very little difference in the final depth to which the water reached. The rate of capillarity is strikingly less than that of any of the other soils and is an excellent example showing the effect of plowing these soils when they are too wet. The soil had become more colloidal than normally, due to puddling, and on drying assumed the form of very hard lumps which, on wetting again, were difficultly permeable to water. In these experiments 45 cubic centimeters of water was poured into the top of the glass tube.

FERTILIZER EXPERIMENTS WITH TARO.

In August, 1910, the station began some fertilizer tests on taro to determine the relative economic value of the use of fertilizers in various proportions and mixtures. These experiments were made in conjunction with the Kalihi Poi Factory and upon their taro plats. These experiments have been completed, and the data accumulated therefrom present some results of considerable practical value to taro growers, and in addition are of some scientific value.

The field was divided up into seven plats, each approximately one-twentieth of an acre in area. The fertilizer was applied on August 5 and the taro planted on August 15. To plat No. 1 super-

phosphate and sulphate of potash were added; to No. 2, nitrate of soda, superphosphate, and sulphate of potash; to No. 3 no fertilizer was added; No. 4, ammonium sulphate, superphosphate, and sulphate of potash; and No. 5 received ammonium sulphate only. The same fertilizer was applied to plats 6 and 7 as to No. 4 except that in the case of No. 6 it was applied on September 16, just before planting, while on No. 7 it was applied two months after planting in order to determine if the time of application would cause any great variation in results.

On August 29 the plants in plat No. 2 appeared to be about twice as large as the check plat, in plat 1 they were smaller, while in 4 and 5 they were about the same size as in the check plat. On September 12 the plants in plat 1 had assumed a yellowish color and were still smaller than those in the check plat. In plat 2 they were still larger than the check plat, but also were yellow. Plats 4 and 5 at this date showed great improvement, and the plants were larger than in any of the other plats and of better color, No. 5 appearing especially green. The final results of the experiments are shown in detail in the following table:

Effect of various fertilizers on taro.

No. of plat.	Fertilizer applied.	Amount per acre.	Yield of taro.	Yield of poi.	Percentage of poi in taro.
		Pounds.	*Pounds.*	*Pounds.*	
1	Superphosphate	450	1,499	1,050	70.0
	Sulphate of potash	450			
2	Nitrate of soda	400	1,751	1,010	57.6
	Superphosphate	450			
	Sulphate of potash	400			
3	No fertilizer		1,231	920	74.7
4	Ammonium sulphate	300	1,702	1,270	74.6
	Superphosphate	450			
	Sulphate of potash	400			
5	Ammonium sulphate	300	1,215	800	65.8

These experiments, while they were carried through only one season, indicate the economic value to be derived from the application of ammonium sulphate, superphosphate, and sulphate of potash to taro. In the second column are shown the weights in pounds per acre, the plats used being only one-twentieth of an acre in size; hence only one-twentieth of these weights were applied on each plat. The yields of taro and poi are given in pounds per plat and not in acreage figures. The weight of taro does not include leaves, but only the marketable root bulbs. Column 5 represents figures obtained in factory.

It is clearly evident from these results that the effect of nitrate of soda is to produce a bulb of greater weight and volume than any of the other fertilizers, but in so doing it causes a decrease in carbohydrate content, from which some doubt arises as to its economic value as a

fertilizer, even though it produced 90 pounds more poi than the check plat. The mixture used in plat No. 4, namely, ammonium sulphate, superphosphate, and sulphate of potash, while it produced an increased yield of 350 pounds poi more than the check plat, does not produce an abnormal growth of the plant as in plat No. 2. This is shown by the fact that there is only 0.1 per cent difference in the percentage of poi in taro obtained from this plat and the check plat, which indicates the normal development of carbohydrates in the root bulb, which results are to be desired in all fertilizer applications.

The fact that taro is grown under soil conditions similar to those in which rice is grown suggests the possibility of these plants having the property of assimilating nitrogen in a somewhat similar form. It has been shown [1] that rice is unable to properly assimilate nitrogen when added in the form of nitrates, while on the other hand ammonium sulphate supplies the nitrogen in a form which produces a considerable increase in yields of both straw and grain. However, in the case of taro the nitrate produces a slightly larger root than the sulphate of ammonia, but less starch.

Plats 6 and 7 showed practically no difference in yield, indicating that no difference results from delaying the application of the fertilizer for two months. Also the yield of these plats was practically the same as that from plat No. 4.

SISAL.

During the year a brief study was made of the chemical composition of the sisal plant with a view to ascertaining some possible means of utilizing the enormous waste accruing from the decortication of the leaves. The results of this work have been published in a recent press bulletin.[2] The most attention was given to sisal and henequen, which are cultivated commercially in Hawaii. Investigations were made to determine their value as fertilizer, stock food, and as a possible source of industrial alcohol. Also a quite extensive chemical analysis of the leaves was made.

The most important finding brought out during the work was the identification of the normal acid of the leaf as lactic acid. So far as the author has been able to ascertain, the normal acidity of the leaf has never been determined. F. H. d'Hérelle [3] attributes the strong acidity of the leaf to oxalic acid, which he says is present in part. It is a very noticeable feature of the sisal fiber industry that the corroding of the machinery due to the strong acidity of the leaf is a factor to be considered, which has been overcome to a certain extent by the use of an especially prepared alloy. The Hawaiian Fiber Co. was desirous of knowing the identity of the acid and the

[1] Hawaii Sta. Bul. 24.
[2] Hawaii Sta. Press Bul. 35.
[3] Jour. Agr. Trop., 10 (1910), No. 108, pp. 161–167.

possibility of its commercial value. The result was the discovery of lactic acid, as mentioned above.

The result of the investigation indicates that obviously the best means of utilizing the waste is to return it to the soil as fertilizer. Although the manufacture of industrial alcohol is worthy of consideration, it is by no means promising, owing to the difficulties to be overcome in fermentation and the comparatively low carbohydrate content of the plant, which was found to be only 2 to 7 per cent of the fresh leaf.

EFFLORESCENCE ON LAVA BRICKS.

Among the miscellaneous investigations undertaken by the laboratory within the past year was one upon the occurrence of an efflorescence upon bricks made from ground lava rock. While it does not strictly represent an agricultural industry, still it was considered to be worth an investigation, being related in a way to the study being carried on in the laboratory upon lavas, their disintegration, etc.

The efflorescence was found to be composed of the carbonates or bicarbonates of sodium and potassium, which in some instances have been found to make their appearance in such large quantities as to give a wall made of these bricks the appearance of having been in the path of a snowstorm. So far as the author has been able to find out, these alkali carbonates have never been known previously to appear in this form, nor in such large quantities as an efflorescence.

The brick are made by pressing the ground rock after a slight addition of lime and dampening of the mixture. They are then dried under steam pressure. The conclusion reached was that the lime and the subsequent drying temperature cause the trouble. Sodium and potassium carbonates are not normal products of lava disintegration, although some of the vesicles in lava rock contain a coating of carbonate. Potassium and sodium occur in basaltic lava in the form of complex silicates. The lime at the temperature of the drying kiln probably replaces the sodium and potassium in these silicates and forms caustic soda and potash, which in turn are converted on contact with the air into carbonates and bicarbonates. This work has been presented to the Journal of Industrial and Engineering Chemistry for publication in more complete form.

SUNLIGHT.

The Philippine Bureau of Science for several years past has been engaged in an extensive investigation of tropical sunlight, paying especial attention to the actinic rays. At the request of this bureau the station has carried on a series of experiments extending over a period of one year to test the actinic power of the sun in Hawaii.

The theory has been prevalent that the sun's rays may be divided into classes of which the blue, violet, and ultra-violet rays are

actinic, that is, capable of producing chemical reactions; also that these rays are a factor of great importance in relation to the effect of insolation on the white man in the Tropics. As a means of measuring this actinic power, Dr. R. F. Bacon, of the bureau of science, has utilized a solution of oxalic acid in the presence of uranium acetate. The latter compound acts as a catalyzer and eliminates the error which would ensue from side reactions, such as oxidation or formation of peroxid. The oxalic acid is decomposed by the actinic rays of the sun and the residual oxalic acid determined by titration.

DESCRIPTION OF THE EXPERIMENTS.

The following solution was exposed, in a Jena glass flask, to the direct rays of the sun, the flask being placed away from reflecting walls and on a sheet of dull black paper: Five cubic centimeters of a 1 per cent solution of uranium acetate, 5 cubic centimeters of a 10 per cent solution of oxalic acid, and 20 cubic centimeters of distilled water. This solution was exposed as above from 9 to 12 o'clock a. m. The solution was then titrated with N/10 potassium permanganate, after addition of 25 cubic centimeters of 1:5 sulphuric acid and heating to 60° C. From this titration the percentage of oxalic acid decomposed was determined. The permanganate solution was standardized quite often and all solutions kept stored in a dark place. Also the same flask was used throughout the year, as it was found that the results are affected slightly by using different flasks. It is hardly necessary to present the results in detail, but only the more important points will be brought out.

Maximum, minimum, and mean actinic power.

Month.	Maximum.	Minimum.	Mean.	Month.	Maximum.	Minimum.	Mean.
January	52.20	11.31	36.41	July	50.55	16.59	37.25
February	50.13	18.88	40.49	August	55.53	27.25	43.75
March	53.28	10.46	41.47	September	62.33	19.72	46.49
April	53.98	16.37	42.92	October	54.81	24.74	44.89
May	52.92	23.67	41.56	November	53.07	17.76	42.77
June	52.25	19.86	40.94	December	48.72	19.24	35.35

Column 1 shows the maximum decomposition obtained during the month, in column 2 the figures represent the minimum actinic power for that month, column 3 represents the mean monthly actinic power of the sun. That is, the daily percentage decompositions were added up for each month and the sum total divided by the number of days on which the actinic power was measured. The following curve (fig. 2) illustrates more plainly the variation of the actinic power of the sun throughout the year in Hawaii.

The above curve presents some very striking data, from which it may be readily seen that the actinic power of the sun is governed

apparently by the position of the sun relative to the earth rather than such climatic factors as the rainy season or the hotter months of the year. The fact that the hotter months, namely, June and July, are so extremely low in actinic power further substantiates the finding of other investigators, namely, that the heat rays are not actinic, or at least only slightly so.

It is highly probable that the position of the sun at various stages of the earth's circuit around the sun is a factor to be taken into

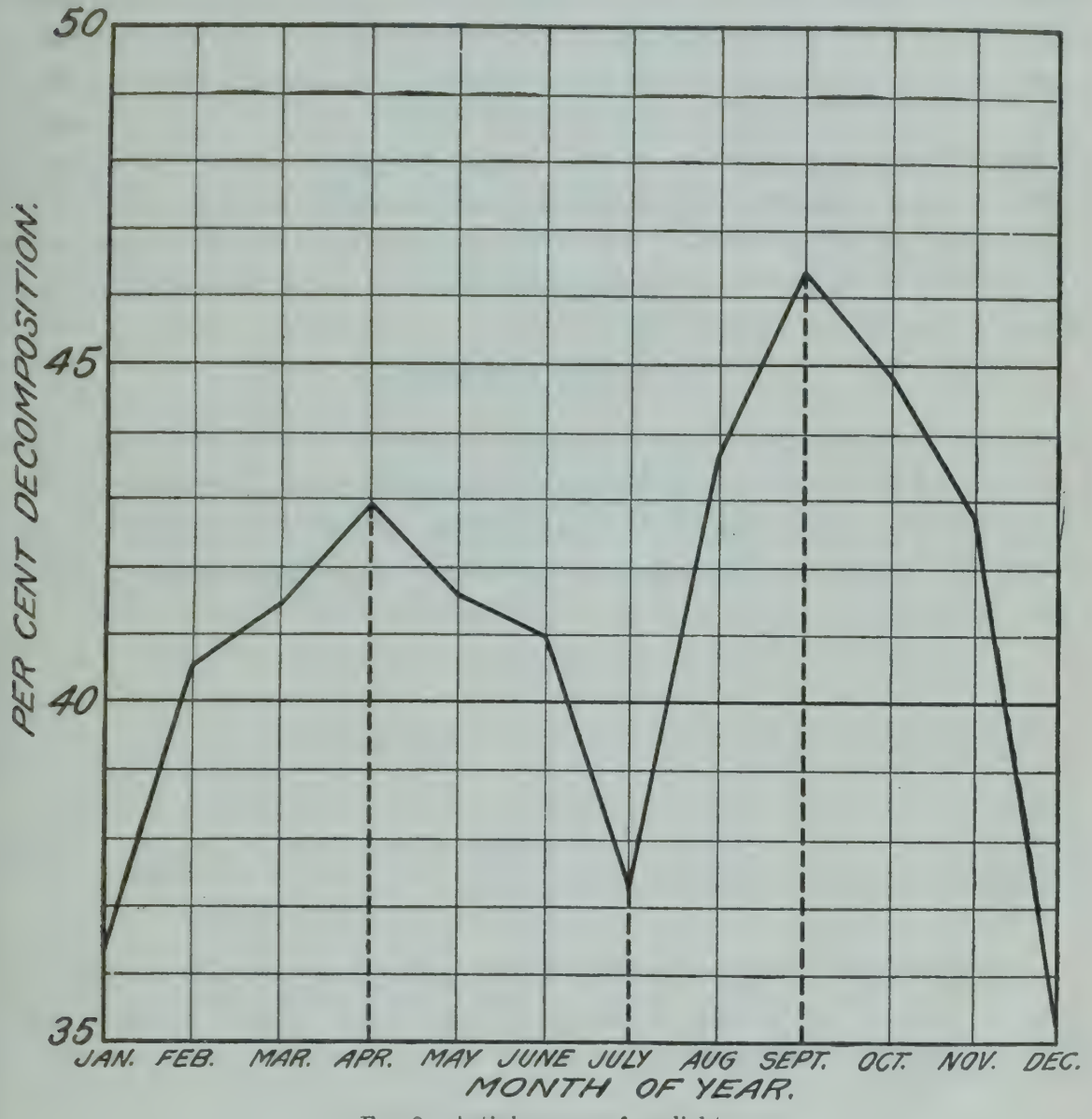

FIG. 2.—Actinic power of sunlight.

consideration. On March 21 and September 21 the sun is directly over the equator, and the curves for these months show the highest points for the first half and second half of the year. In like manner on June 21 and December 21, the months in which the sun reaches its longest distance above and below the equator, respectively, these points on the curve are the lowest and of least actinic power.

It has been found in the investigation that the lowest actinic days are those on which it is raining and cloudy. The mere fact

that the day is cloudy, however, does not necessarily indicate a nonactinic day, as we have found cloudy days on which it is as strong as on many sunshiny days, indicating that the actinic rays to a great extent pass through the clouds. Sunshiny days vary considerably, some being actinic while others are much less so. Quite often hazy days were found to be very strongly actinic but like the sunshiny days, they were not regularly so. It was found to be a regular occurrence that a sunshiny day following a rain of the night before produced very strong actinic rays. For a short time tests were also run in the afternoon from 12 to 3 p. m., and it was found that the afternoon rays were more strongly actinic than the morning rays. That the points on the curve for the first half of the year are so much lower than those of the latter half is probably due to the fact that these months represent the rainy season, during which there were fewer sunshiny days, thus lowering the monthly average, even though the actinic days during this season were less actinic than those of the latter half.

MISCELLANEOUS.

A small amount of miscellaneous analytical work has been done during the year, among which were some analyses of Hawaiian rubber. The following table shows the maximum and minimum results obtained from the analyses of seven samples of crepe form, and represents the average composition of Hawaiian rubber:

Composition of Hawaiian rubber.

Constituents.	Minimum.	Maximum.	Constituents.	Minimum.	Maximum.
	Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
Protein	2.62	3.81	Ash	0.78	1.65
Resin	3.06	4.18	Gum	90.93	92.65
Moisture	.49	.89			

A comparison was also made of the composition of the crepe and biscuit forms of Hawaiian rubber and a sample of Malay crepe rubber, with the following results:

Comparison of crepe and biscuit rubber.

Constituents.	Malay crepe.	Hawaiian crepe.	Hawaiian biscuit.	Constituents.	Malay crepe.	Hawaiian crepe.	Hawaiian biscuit.
	Per cent.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
Proteids	3.50	3.25	5.37	Ash	0.37	1.13	1.40
Resin	2.67	3.55	3.08	Gum	92.84	91.40	88.86
Moisture	.62	.67	1.29				

Hawaiian rubber is shown to contain a higher percentage of ash and resins than the Malay rubber, the latter probably being due to

a difference in the age of the trees as it is known that the resin content of some rubbers decreases as the age of the tree increases. The higher percentage of proteids in the biscuit form is due to the greater pressure under which the crepe rubber is washed.

Another analysis of some importance was that of the trunk of the fern tree (*Cibotium chamissoi*), which is being used to a certain extent as a hog feed, both raw and cooked, on the island of Hawaii. It occurs in immense quantities in districts of Hawaii and its utilization is a factor in the clearing of forests. An analysis has also been made of a sample of soy-bean cake.

Comparative analyses of fern tree trunks and soy-bean cake.

Constituents.	Fern.	Fern (dry basis).	Soy-bean cake.	Constituents.	Fern.	Fern (dry basis).	Soy-bean cake.
	Per cent.	*Per cent.*	*Per cent.*		*Per cent.*	*Per cent.*	*Per cent.*
Moisture	69.38	.....	15.62	Starch	20.92	68.32	.....
Ash	.33	.....	24.52	Fat	.....	.....	18.76
Nitrogen	.18	.....	2.76	Sodium chlorid	.....	.....	23.05
Protein	1.12	3.65	17.25	Nitrogen free extract and crude fiber	.....	.....	23.77
Phosphoric acid	.10	.32	.08				
Reducing sugar	3.99	13.03	.....				
Nonreducing sugar	.24	.78	.....				

The high percentage of salt to be found in the soy-bean cake is due to the large quantities added during the fermentation which the mash undergoes in the process of soya sauce manufacture.

THE DETERMINATION OF SULPHUR AND CHLORIN IN THE RICE PLANT.

By Alice R. Thompson, *Assistant Chemist.*

In so complex an organism as one of the higher plants it is difficult even to suggest correctly the functions of the various elements found in it. Besides many other investigations, Loew [1] has defined the uses of phosphoric acid, sulphur, and chlorin in the plant.

Phosphoric acid is found in organic compounds such as lecithin, inosite, hexaphosphate, nuclein, and chlorophyll; also in inorganic form as calcium, magnesium, and potassium phosphate. Inorganic phosphate is found in small quantities in the foliage of plants, while the seeds contain almost no mineral phosphate, but usually large amounts of phosphorus in organic combination.[2]

Sulphur is also found in definite chemical organic compounds in the plant. Osborne,[3] who analyzed a large number of sulphur albuminoids in seeds, found sulphur in constant molecular amounts in the various purified substances he obtained. For instance, edestin contains 0.884 per cent SO_3, legumin, 0.385 per cent; gliadin of wheat, 1.027 per cent.

Sulphur also occurs as mustard oils in plants; mustard seed and onions are common examples of plants containing these oils.

Sulphur in mineral form as sulphates occurs usually in smaller quantities in plants. Arendt, Ulricht, E. Schulze, Berthelot and Andre, and Fraps [4] investigated the mineral form of sulphate in plants and found it to vary in different parts of the plant as well as in plants belonging to different families. Sulphates are also formed from the organic sulphur in germinating seeds.

Euler [5] believes that sulphur is held in reserve form in the plant as cystin, a dithio-diamido-dilactic acid—

$$S-CH_2-CH\ (NH_2)\ COOH$$
$$S-CH_2-CH\ (NH_2)\ COOH$$

which is an exceedingly energetic compound, from which hydrogen sulphid is split off in small but continuous amounts for the formation of albuminoids.

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[1] U. S. Dept. Agr., Div. Veg. Physiol. and Path. Bul. 18.

[2] New York State Sta. Tech. Bul. 1, p. 7.

[3] Connecticut State Sta. Rpt. 1900, pp. 442–471; Jour. Amer. Chem. Soc., 24 (1902), No. 2, pp. 140–167.

[4] North Carolina Sta. Rpt. 1903, p. 67.

[5] Grundlagen und Ergebnisse der Pflanzenchemie. Brunswick, 1909, pts. 2–3, p. 146.

Whether or not chlorin is a necessary ingredient of plants is quite unknown. Many investigators believe the presence of chlorin to be superfluous in plants. As chlorin is present in most soils as the very soluble salts of sodium, potassium, and magnesium, the plant absorbs it as it absorbs any soluble salt in the soil. Also, if chlorin be present in considerable amounts, it acts as a strong poison to the plant. Euler[1] points out that no organic compound containing chlorin in molecular combination has been isolated from any plant. Nobbe, Siegert, et al.,[2] in their experiments with buckwheat, showed that chlorin is required in this instance to carry the plant to maturity. Many believe that it is necessary for the translocation of carbohydrates, helping to render starch more soluble. Others (A. Mayer[3]) hold that even buckwheat can be brought to maturity without chlorin.

In this paper the author has sought to show the sulphur and chlorin content of the parts of the rice plant at three stages of growth, and to determine the effect, if any, of fertilizer on the sulphur and chlorin composition of the plant grown in natural soil conditions and in sand cultures; also to determine the amounts of sulphur and chlorin contained in the rice field soil and water. The phosphoric acid content of the plant has been given in a previous publication.[4]

From the obvious increase of sulphate ions in rice plants grown in silica sand and fertilized with ammonium sulphate, conclusions may be drawn that ammonium sulphate as such is absorbed by the plant. Free ammonia was found in the foliage of plants grown in the rice fields, and, as has been shown in a bulletin of the station,[5] the rice plant makes the best growth when nitrogen is supplied in the form of ammonia.

METHOD OF ANALYSIS.

The method followed in the analysis of the rice samples for total sulphur is that of Osborne,[6] slightly modified by Hart and Peterson[7] in that the water was not boiled off from the saturated sodium hydroxid solution and the melt from the sodium peroxid fusion of the rice sample was boiled out with water and not with acid. The author found that not enough emphasis has been placed on the influence of sulphur from the gas burners on sulphur determinations. In the first analyses made, the fusions were made over alcohol lamps,

[1] Loc. cit.

[2] Landw. Vers. Stat., 4 (1862), pp. 318-340; 7 (1865), pp. 371-386; 13 (1871), pp. 330-400; cited by Euler, Grundlagen und Ergebnisse der Pflanzenchemie. Brunswick, 1909, pts. 2-3, p. 149.

[3] Jour. Landw., 49 (1901), No. 1, pp. 41-60.

[4] Hawaii Sta. Bul. 21.

[5] Hawaii Sta. Bul. 24.

[6] Loc. cit.

[7] Wisconsin Sta. Research Bul. 14, p. 2.

but the solutions were boiled in beakers covered with watch glasses over gas burners. The resulting blank determinations were high in sulphur, amounting to 0.03 per cent SO_3. All subsequent determinations were therefore made in a room shut off from gas fumes and both fusion and boiling made over alcohol lamps. The resulting blank determinations were practically nil in sulphur, as shown below:

Blanks on sodium peroxid.

	Per cent SO_3.
Fused over alcohol lamp but solution boiled over gas flame	0.0009
Fused and solution boiled over alcohol lamps	.0001

Blank on reagents bromin and nitric acid negligible.

In acidifying the alkaline solution of the fused melt it was noticed that a very good indication of the neutral point was the continuous effervescence due to carbon dioxid or hydrogen peroxid gas that occurs just after the solution becomes acid.

Before this stage is reached the effervescence resulting from addition of acid does not continue when addition of acid ceases.

The precipitate of barium sulphate was treated with hydrofluoric acid and a few drops of sulphuric acid and ignited a second time to remove traces of silica that in a few cases contaminated the precipitate.

Duplicates on each sulphur determination were made and checked usually within 0.02 and 0.03 per cent.

The mineral sulphur was determined by stirring the sample with 100 cubic centimeters of cold 1 per cent hydrochloric-acid solution and allowing it to stand an hour before filtering. (In the case of the starchy grain the sample was boiled with the solution to render it soluble. No hydrolysis of sulphate occurred by this method, as no trace of sulphate was ever found in the grain.)

Chlorin was determined by the Volhard method (official method).[1]

The samples of rice plants for this work were collected March 23, April 19, and May 15, 1912, 10 clumps of the plants being selected from each of two plats at the trial grounds. The first series of plants was taken before the flowering and divided into foliage and roots for analysis. The second series was taken at the time of full-stage flowering and divided into panicles, leaves, stems, and roots. The third series was taken at maturity and divided into grain, chaff, leaves, stems, and roots. This plan follows that given in a previous publication of this station.[2]

The plats from which the rice was taken were the unfertilized and the complete ammonium sulphate fertilizer plats.

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[1] U. S. Dept. Agr., Bur. Chem. Bul. 107 (rev.), p. 23.

[2] Hawaii Sta. Bul. 21.

RESULTS OF ANALYSES.

The following table shows the sulphur and chlorin composition of the rice plant at the first harvest and compares the composition of plants grown in the two plats; one unfertilized, the other fertilized with ammonium sulphate, superphosphate, and potassium sulphate.

Sulphur and chlorin in rice at the first harvest.

(Water-free basis.)

	Check plat.			Complete fertilizer plat.		
	Foliage.	Roots.	Total plant.	Foliage.	Roots.	Total plant.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Total SO_3	0.489	0.492	0.491	0.393	0.430	0.401
Mineral SO_3	.057	.208	.107	.079	.188	.102
Cl	.628	1.090	.780	.605	.949	.679

In this series the total sulphur percentage is higher than at any other period of growth. It is about equally distributed between the foliage and roots. In the samples from the check plat the total sulphur trioxid is about 0.1 per cent higher than it is in those from the complete fertilizer plat. This may be due to the fact that the plants in the complete fertilizer plat were much larger and had made more growth.

The percentage of mineral sulphur is highest in the roots, being almost four times as high in the roots as in the foliage; but it is much less than the total sulphur, showing the formation already made of organic sulphur in the plant. Chlorin is also highest at this first period and, like sulphur, is found in largest percentage in the roots.

Sulphur and chlorin in rice at the second harvest.

(Water-free basis.)

	Check plat.					Complete fertilizer plat.				
	Panicles.	Leaves.	Stems.	Roots.	Total.	Panicles.	Leaves.	Stems.	Roots.	Total.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Total SO_3	0.245	0.395	0.169	0.305	0.2453	0.245	0.344	0.157	0.313	0.2294
Mineral SO_3	.000	.056	.009	.143	.0374	.000	.037	.036	.162	.0517
Cl	.200	.370	.349	.490	.3534	.174	.345	.352	.446	.3437

At the second period the difference in composition of the plants grown in the two different plats has become nil and no effect of fertilizers is shown in the percentage composition, although the plants were much larger and heavier in the complete fertilizer plat.

The percentage of sulphur in the total plant has decreased from the first period, the leaves having the highest content in sulphur, the stems lowest.

No mineral sulphur was found in the panicles, but this form was relatively high in the roots and leaves.

Chlorin had also decreased in percentage amount and was quite low in the panicles and high in the roots.

Sulphur and chlorin in rice at the third harvest.

(Water-free basis.)

	Check plat.						Complete fertilizer plat.					
	Chaff.	Grain.	Leaves.	Stems.	Roots.	Total plant.	Chaff.	Grain.	Leaves.	Stems.	Roots.	Total plant.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
SO_3	0.166	0.241	0.256	0.126	0.247	0.1933	0.118	0.231	0.195	0.120	0.292	0.1763
Mineral SO_3	.000	.000	.000	.000	.087	.005	.000	.000	.000	.000	.121	.008
Cl	.261	.040	.338	.605	.376	.306	.246	.038	.419	.522	.392	.314

At the third period the fertilizers show no effect on the composition of the plant.

Total sulphur is very small in the stems and chaff and about 0.23 per cent in the other parts of the plant.

Mineral sulphur is found only in the roots, showing that the plant has used up the mineral sulphur in the formation of organic material.

Chlorin is practically absent from the grain, though high in the stems.

Mature rice plants from plats under different fertilizer conditions were selected, 10 clumps from a plat, and analyzed separately to determine any influence of fertilizer on the sulphur, chlorin, or phosphoric acid composition on the straw and paddy of rice. In the following table the results show no difference in the sulphur or chlorin composition of these plants grown in the different plats. The ammonium sulphate plat shows a slight depression of the phosphoric acid absorbed by the rice plant.

Sulphur, phosphoric acid, and chlorin in rice plant.

[Water-free basis.]

Fertilizer.	No. of plat.	Straw.			No. of of plat.	Grain.		
		Total SO_3.	P_2O_5.	Cl.		Total SO_3.	P_2O_5.	Cl.
		Per ct.	*Per ct.*	*Per ct.*		*Per ct.*	*Per ct.*	*Per ct.*
Check	24	0.204	0.278	0.445	34	0.255	0.926	0.058
Sulphate of potash, superphosphate	25	.193	.215	.449	35	.262	.954	.045
Ammonium sulphate, sulphate of potash	26	.189	.291	.461	36	.228	.861	.044
Ammonium sulphate, superphosphate	27	.207	.231	.511	37	.249	.879	.054
Check	28	.171	.245	.478	38	.247	.900	.051
Ammonium sulphate, superphosphate, sulphate of potash	29	.162	.255	.502	39	.254	.824	.056
Ammonium sulphate, superphosphate, sulphate of potash	30	.191	.242	.544	40	.235	.813	.050
Ammonium sulphate	31	.199	.240	.544	41	.250	.815	.046

The following table shows the amount of sulphur, chlorin, and phosphoric acid absorbed from the soil by the rice plant and indicates the possibility of sulphur fertilizations being required by a crop that absorbs about half as much sulphur as it does phosphoric acid for organic material.

That considerable amounts of sulphur are removed by various crops from the soil is shown by Hart and Peterson [1] who suggest the need of fertilization of soils by sulphur.

Boullanger [2] showed the favorable effect of sulphur on the bacterial condition of the soil. Demolon [3] obtained increased yields by the use of flowers of sulphur as fertilizer and believes it is transformed into sulphates in the soil. Bernhard [4] also secured larger crops by the use of sulphur fertilizer.

Amount per acre of sulphur, phosphoric acid, and chlorin absorbed by the rice plant.

	Check plat.	Complete fertilizer plat.		Check plat.	Complete fertilizer plat.
	Pounds.	*Pounds.*		*Pounds.*	*Pounds.*
SO_3	9.5	11.9	Calculated as S	3.8	4.8
Cl	14.9	21.1	Calculated as P	12.6	18.4
P_2O_5	28.8	42.0			

A partial analysis of the soil obtained at the rice trial grounds is shown in the table below:

Analysis of the soil obtained at the rice trial grounds.

	Per cent.
Total SO_3 (Osborne method)	0.123
Acid soluble SO_3 (official method)	.031
Water soluble (1 per cent HCl.)	.008
Acid insoluble residue SO_3 (Osborne method)	.022
Iron precipitate from official soil solution (Osborne)	.032
Steam distillation of soil, SO_3 determination	.001
Moisture	5.58
P_2O_5	.671
Cl	.016

In the Osborne method of determination, the melt solution was filtered in an alkaline condition so that the iron and titanium were separated from the solution in which the sulphate was precipitated. No ammonium salts were thus introduced, and ferric chlorid was eliminated.[5] In the official method, however, the iron was pre-

[1] Wisconsin Sta. Research Bul. 14, p. 5.
[2] Compt. Rend. Acad. Sci. [Paris], 154 (1912), No. 6, pp. 369, 370.
[3] Ibid., No. 8, pp. 524–526.
[4] Deut. Landw. Presse, 39 (1912), No. 23, p. 275.
[5] North Carolina Sta., Rpt. 1902, p. 50.

cipitated by ammonia in the cold, according to Treadwell,[1] so that no basic iron sulphate would tend to form.

The results indicate that the sulphur in the soil is present largely in organic form, since the acid soluble and water soluble sulphur are relatively so small. No trace of sulphid was found on boiling the soil with hydrochloric acid. Doubtless the presence of large amounts of iron in the soil results in the formation of insoluble basic compounds of sulphur and this may explain the noneffect of sulphur fertilizer on the composition of rice plants grown in the soil, for, as will be seen later, in silica sand cultures, the composition is much affected.

The soil was subjected to steam distillation and only 0.001 per cent SO_3 in the distillate was found oxidized with bromin.

The soil contains an abundance of phosphoric acid but no large amount of chlorin.

In the following table is shown the composition of the water entering the rice field and the water standing on the last plat.

Analyses of water used on rice fields.

Constituents.	Artesian water entering rice trial grounds.	Water from last plat in field.	Rain water collected at experiment station.
	Parts per million.	*Parts per million.*	*Parts per million.*
CaO	6.5	6.6	.....
MgO	8.7	10.1	.....
Cl	73.8	63.9	.....
SO_3	8.8	9.0	3.41
NH_3	None.	Trace.	.....

This irrigation water flows over the field and amounts to 25,700 gallons per acre per day and doubtless the plant obtains some of its chlorin and sulphur from the water standing about its roots.

Sulphur trioxid amounted to about 9 parts per 1,000,000 and chlorin to 70 parts per 1,000,000.

Analysis of rain water collected at the experiment station showed 3.41 parts per million of SO_3. But as the rice trial grounds are situated farther from the hills, they received almost no rainfall this year and the soil would receive no sulphur from this source.

The author took advantage of samples of rice grown in pot cultures for nitrogen work as outlined in Bulletin No. 24 of this station. The plants had received in addition to a basic fertilizer lacking nitrates, as given by MacDougal,[2] calcium sulphate and the several forms of nitrogen as shown in the table.

[1] Analytical Chemistry.—Quantitative Analysis. New York and London, 1909, 1. ed., vol. 2, p. 282.
[2] Text-book of Plant Physiology, New York, 1901, p. 225.

Total sulphur as SO_3 in moisture-free material (pot cultures).

Fertilizer.	Straw.			Paddy.		
	Trial grounds, submerged.	Silica sand, submerged.	Silica sand, not submerged.	Trial grounds, submerged.	Silica sand, submerged.	Silica sand, not submerged.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Check	0.215					
$(NH_4)_2SO_4$	.239	0.667	0.449	0.328	0.405	0.444
$Mg(NO_3)_2$	.221	.380	.262		.318	
$NaNO_3$	.388		.274	.263		
$Ca(NO_3)_2$	.267	.343		.319		
NH_4NO_3		.508	.310		.294	
$(NH_4)_3PO_4$		.341			.302	
Soy bean cake				.327		

In this table no consistent influence can be seen on the sulphur composition of the plants grown in pots containing trial-ground soil. But in those plants grown in the silica-sand pots the total sulphur content is higher in every case and constantly higher when the soluble ammonium sulphate was the fertilizer added. In the following table the mineral sulphur in the plants is shown.

Mineral sulphur as SO_3 in the plants.

Fertilizer.	Straw.			Paddy.		
	Trial grounds, submerged.	Silica sand, submerged.	Silica sand, not submerged.	Trial grounds, submerged.	Silica sand, submerged.	Silica sand, not submerged.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Check	0.052					
$(NH_4)_2SO_4$	.106	0.435	0.148	None.	None.	
$Mg(NO_3)_2$	.069	.163	.070		None.	
$NaNO_3$	.698		.076	None.		
$Ca(NO_3)_2$	.061	.152		None.		
NH_4NO_3		.309	.098		None.	
$(NH_4)_3PO_4$		.175			None.	
Soy bean cake				None.		

These results indicate the increase of total sulphur in the straw to be almost entirely due to mineral sulphur absorbed by the plant.

Phosphoric acid in moisture-free plants.

Fertilizer.	Straw.			Paddy.		
	Trial grounds, submerged.	Silica sand, submerged.	Silica sand, not submerged.	Trial grounds, submerged.	Silica sand, submerged.	Silica sand, not submerged.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Check	0.227					
$(NH_4)_2SO_4$	.176	0.162	0.285	0.784	0.849	0.924
$Mg(NO_3)_2$	.247	.262	.296		.761	
$NaNO_3$	.190		.253	.812		
$Ca(NO_3)_2$	.207	.200		.671		
NH_4NO_3		.158	.252		.750	
$(NH_4)_3PO_4$		.201			.802	
Soy bean cake				.836		

The phosphoric acid content was found to be fairly constant throughout this series of plants.

In the table given below are the analyses of plants grown by the author in silica-sand pots with the view of verifying the previous results. The chlorin absorbed was about twice as high as that absorbed by the rice plant grown in normal soil conditions. These results with silica-sand cultures show the sulphur fertilizer is not rendered insoluble to the plant as is the case in soil cultures. They show the probability of the absorption of ammonium sulphate as such by the rice plant as so much mineral sulphate is found in the foliage, and free ammonia was determined in the water solution of two rice-plant samples.

Plants grown submerged in silica sand.

	Ammonium sulphate.	Calcium sulphate.	Check.
	Per cent.	*Per cent.*	*Per cent.*
Total SO_3	0.852	0.531	0.409
Mineral SO_3	.629	.312	.095
Cl	1.231	.969	1.266

The author made some determinations of phosphoric acid in the solutions obtained from sulphur determinations by fusion with sodium peroxid. The molybdic precipitate was dissolved and reprecipitated to exclude silica. The results as given in the following table compare favorably with those obtained by ignition with magnesium nitrate (official method):

Content of phosphoric acid as shown by different methods.

Number.	Na_2O_2 method.	Air-dried material, $MgNO_3$ method.	Number.	Na_2O_2 method.	Air-dried material, $MgNO_3$ method.
	Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
8 (grain)	0.731	0.726	18 (straw)	0.272	.....
9 (straw)	.163	.138	35 (grain)	.740	0.771
12 (straw)	.261	.223	36 (grain)	.702	.842
15 (grain)	.626	.593			

Also results obtained by boiling samples with HCl and HNO_3 compared with those obtained by boiling with H_2SO_4 and KNO_3 (official method)[1] are as follows:

[1] U. S. Dept. Agr., Bur. Chem. Bul. 107 (rev.), p. 2.

Content of phosphoric acid as shown by different methods.

Number.	Straw.		Number.	Grain.	
	H_2SO_4-KNO_3 method.	HCl-HNO_3 method.		H_2SO_4-KNO_3 method.	HCl-HNO_3 method.
	Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
24	0.255	0.189	34	0.831	0.249
25	.197	.201	35	.842	.225
26	.266	.182	36	.771	.223
27	.212	.198	37	.781	.216
28	.294	.202	38	.803	.255
29	.233	.164	39	.730	.212
30	.222	.154	40	.725	.221
31	.220	.188	41	.727	.230
32	.260	.268	42	.778	.245
33	.267	.199	43	.771	.223

It is evident that the results obtained from the straw analyzed by the two methods are not greatly different, but those obtained by boiling the grain with aqua regia until a colorless solution results are about one-third as high as those obtained by the sulphuric-acid and potassium-nitrate method. Although the solution of the grain obtained by boiling with HCl and HNO_3 becomes practically colorless, organic matter is still present, as shown by the charred mass that results if it is boiled to dryness. The starch may be oxidized to some organic acid that resists oxidation and interferes with the precipitation of the phosphomolybdic precipitate.

Thanks are due to Dr. W. P. Kelley, who suggested this work on sulphur in rice plants, and to Dr. E. V. Wilcox and Mr. William McGeorge, who gave helpful suggestions throughout the work.

REPORT OF THE AGRONOMIST.

By C. K. McClelland.

COTTON.

The work in agronomy for the year has been along the same lines as in previous years, although the work with cotton has been given the most attention. This work with cotton was deemed of first importance because the culture of the crop is not yet upon a paying basis, and it was thought that an effort should be made to get all information possible in regard to the crop so that it would be possible to suggest the proper methods of management. Many of those who planted cotton within the past few years have been compelled to abandon it, owing to improper conditions of environment or to the ravages of the pink bollworm, which continues to be the principle insect destroyer of cotton.

During the year the agronomist visited the fields of cotton upon Kauai, and the assistant in agronomy visited those upon the leeward side of Hawaii. Also from time to time as opportunity offered, trips were made to the various fields situated upon Oahu.

A press bulletin upon Cultural Methods for Controlling the Cotton Bollworm [1] was published in the fall of 1911, showing what success was obtained in fighting the bollworm by the use of lantern traps, by pruning, and by clean culture. Later, another press bulletin [2] was issued giving general directions for growing the crop and giving a discussion of various varieties and practices, with such recommendations as could be derived from the study of the crop on Oahu and upon the other islands.

Briefly, these suggestions were to attempt to grow the crop only on lower elevations or at least in fully protected places; to grow Caravonica in extremely dry locations and Sea Island, if preferred, in moister situations, but that so long as the bollworm is present to grow it as an annual.

It will be sufficient here to add that because of the unusual extreme drought during the winter and spring months the prospects for the 1912 crop are far from promising. Some of the planters waited until late in the spring for rains which never came to do their pruning, and finally were compelled to go ahead without the benefit of rains

[1] Hawaii Sta. Press Bul. 32.

[2] Hawaii Sta. Press Bul. 34.

to start the new growth. Under such conditions high pruning is advisable, but in some cases low pruning was resorted to, and the buds which started were not able to continue their growth but remained at a comparative standstill until into the month of June. Under other conditions where the work was done in the fall or where rains were more abundant in the spring the prospects are brighter and a medium crop at present is assured. With the prevailing low price for cotton and with a seemingly limited demand, together with the great damages still being worked by the bollworm, it would seem that prospects for cotton in general are not especially bright.

Some samples of saw-ginned and roller-ginned Caravonica cotton were submitted to a New England firm which makes a specialty of carded cotton for woolen mills. The samples were run through the picking and carding machines and the shrinkage or waste was determined. The saw-ginned cotton suffered a loss of $9\frac{1}{8}$ per cent and the roller-ginned only $7\frac{1}{4}$ per cent, which is about the same, the firm says, as is lost from Peruvian cotton. They consider the roller-ginned cotton, since it has about the same roughness as the Peruvian cotton, to be equal to it and allowed $18\frac{1}{2}$ cents a pound for it, which was the price of Peruvian upon the market there at that time. For the saw-ginned cotton they allowed $18\frac{1}{8}$ cents, or three-eighths cent less per pound.

At this price for cotton, not considering the cost of the roller gin, which costs double the amount that the saw gin costs, the excess of cost of ginning upon the roller gin greatly exceeds the extra amount which was received for the cotton; and if the price were greater the difference would be still greater in favor of the saw ginning. If the work is carefully done, then the profit is greater by using the saw gin, but if carelessly done and if the gin is run at too great a speed the damage may be greater than here reported, and the difference in price would be more.

This opinion, coming from a firm of recognized authority and who use cotton in large amounts annually, may be taken as settling the question of the use of the saw gin, which has been debated among the cotton growers of Hawaii. To one buying a gin, the difference is in favor of the saw gin, but to one already operating a roller gin the difference is not such as would justify an exchange of gins.

RICE.

The rice experiments have been continued as heretofore, and, although the rice-trial grounds will have to be given up at the end of this year, another small field will be obtained and the work continued. The introduction of the Japanese varieties among the Chinese growers progresses very slowly. The growers are loath to plant a rice for which they have in the past had to accept a lower

price than they obtained for their other varieties. However, seed of two varieties was given to three growers in considerable quantities, and as these two varieties have been grown in Hawaii for several generations, an effort will now be made to give them a thorough culinary test and determine if possible what has been the effect upon them of the soil or climate.

In this connection it is interesting to note that in the Kapaa District of Kauai, a Japanese was found who claims to have been growing the Shinriki variety for the past nine years and that he finds it as good to-day as it was in the beginning. In the vicinity of Pearl Harbor, where this variety is grown on a large scale from seed obtained from the station, it is said that the Japanese are eager to obtain it and that the crop is rushed as soon as harvested to the mill and prepared at once for their use. From these two encouraging reports it would seem possible in time to grow a rice that will completely fill the requirements of the Japanese consumers.

SEED DISTRIBUTION.

During the year there has been quite a demand for seed of various kinds and it has not always been possible from our limited stock to fill all demands. Seeds of soy beans, pigeon peas, peanuts, broom corn, alfalfa, velvet and jack beans, various sorghums, and also roots of several prominent grasses have been sent out in answer to demands. Especially among the homesteaders has there been a great demand for these seeds.

DRY FARMING.

Some cooperative experiments were attempted upon a dry-land basis in a district out from Honolulu which is noted for its dryness, but no results have been obtained, for the reason that while heretofore in this region there has always been some rain during the year, for this once at least the rains failed entirely, and all the various crops tried have completely succumbed to the drought. The wind across this region is strong during most of the time and this, together with the lack of a percolating rain, caused the failures.

A small grass garden was started in the fall upon a very dry field located upon Magazine Street and a number of grasses and legumes were planted. Rescue grass and crimson clover were very promising at first but in the end probably the best showing was made by the Australian water grass. At present only this grass and some alfalfa seem to be alive, the others being dried up and withered by the extreme wind and drought prevalent there. Berseem and bur clover matured seeds, also rescue grass, but the majority of the grasses did not.

BROOM CORN.

The experimental work with broom corn has been continued upon a small scale. That planted in April, 1911, yielded at a rate of 311 to 658 pounds of brush per acre, the lower yield being obtained from the outer edge of the field near some algaroba trees which are far reaching in their influence. This brush was of excellent quality and was from 24 to 30 inches in length, which is longer than is desired by the broom manufacturers. Closer planting under the same conditions would have restricted the length. The crop occupied the land but 90 days and was sold for 6½ cents per pound.

The crop was allowed to ratoon and proved a failure, the yield being much less than at first while the quality was very inferior, each stalk having coarse central stems in the brush. Perhaps better conditions of moisture would have produced a better result, but a ratoon crop under our dry summer conditions is inadvisable.

Another small area was planted December 20, 1911, from seed obtained in San Francisco. A period of dry weather followed with late winter rains. The brush obtained from this planting was of about the same quality as that obtained in the previous ratoon crop. This poor quality might be due either to the use of run-out seed, to the effect of the dry weather in the early stages of growth, or to the effect of the cool weather at the time of heading out. Some of this same seed was again planted April 4, 1912, and began heading out about the middle of June, the heads at this season being almost entirely free of the objectionable center stems. It would seem from this one experience that fall planting is undesirable; but another planting will be made to try and find out the exact cause of such poor quality.

From experiments thus far made it appears that there is a small profit only to be obtained in growing broom corn. As corn produces well in the winter months, it would be well to grow corn at this time and then to plant the broom corn after the corn in April or May. Where only small areas are grown and no machinery is used a good plan is to plant the broom corn in the rows between the corn, and especially if the corn is to come off late in the spring. In midsummer, provided there is sufficient moisture to start the seed, soy beans or other legume may in turn be planted between the rows of broom corn for green manure or other purposes. In this manner a return of about $30 per acre may be obtained for the use of the land for only about 90 days.

GRASSES AND FORAGE PLANTS.

The problem of grasses and legumes for hay, soiling crops, and pasture is very important, although for several years some attention to this subject has been given by the managers of the various ranches

upon the different islands. The requirements are varied, and the conditions of environment are so greatly changed within short distances that it makes the problem even more difficult. The greatest demand of course is for suitable grasses for pasture, and for different ones that will be useful at different times. For winter months or for summer months; for wet districts or for dry; for districts with both a wet and a dry season; for low or for high elevations; for reasonably good and for poor rocky barren soils—these are the variations of environment for which it is difficult to obtain suitable crops.

From time to time upon the ranches a number of grasses have been introduced and tried out with the hope of finding a few which would answer requirements and thrive under the given conditions of environment. Although doubtless as many as 50 different species have been tried but few of them have been found that were especially valuable.

Another want is felt by the dairymen for a legume crop to grow in rotation with sorghum in the winter months for soiling. Alfalfa when once seeded is too valuable a crop for short rotations; soy beans have not produced desired amounts; the same was true for cowpeas, which were badly attacked by aphids; velvet beans and jack beans grew too slowly to give any satisfaction; and each crop tried seemed to be lacking in some important point.

For hay there is a considerable demand only in the larger towns and also by the Government for the Army horses and mules. Considerable quantities of Ajax wheat hay are brought in from California. Upon the plantations cane tops furnished the greater part of the roughage in the rations. Some alfalfa is imported and there is a small amount grown and cured here. Pará grass and Guinea grass are used to some extent, but these, like alfalfa, are more often used as soiling grasses and fed when freshly cut. Rhodes grass and Natal redtop have been recommended for hay crops under various conditions, the former being especially drought resistant.

In order to glean what lessons have been learned by these various experimenters and to be able to give their experience to others interested, it is the intention to make a careful study of these trials upon the different ranches from time to time as opportunity offers, and already some important lessons have been derived from a study of the methods used in improving pastures and conditions in general upon the Princeville plantation near Hanalei, Kauai.

RANGE IMPROVEMENT.

The ranch known as Princeville plantation consists of about 12,000 acres in the Hanalei district of Kauai varying in elevation from sea level to 1,000 feet above. On the lower lands are now some 700 acres in rice while the upper lands, several thousand acres in extent, are precipitous and covered with forest. The pasture lands lie mostly

between 300 and 800 feet in elevation and are cut up here and there by several deep gulches. In places these gulches are very wide and formerly were swampy and many animals were lost in them. There was also a considerable loss in the high lands from cattle falling over the bluffs or from the narrow trails along the gulches.

The pasture lands were covered with a heavy growth of lantana and of guava, averaging from 15 to 18 feet in height. To subdue these shrubs, buffalo grass (*Stenotaphrum secundatum*) was introduced in 1902, 100 acres being planted, and from then until 1908 about 900 acres more were planted with this grass.

In 1905, Mr. W. F. Sanborn, the present manager, was placed in charge and a more scientific and practical effort made to achieve good results. From the practical point of view it was reasoned (1) that land covered with guava and lantana, neither of which were of value as forage, could carry only a small fraction of as many cattle as it could if these shrubs were destroyed; (2) that if the innutritious and unpalatable grasses, such as Hilo grass and other native grasses, were supplanted by better ones, this would also help to increase the carrying capacity of the pastures; (3) that if the quality of the cattle were improved by using pure-bred sires from some credited beef breed, within a few years it would be possible to produce a pound of beef upon much less feed than was required to produce that amount in scrub cattle; and (4) that by draining the swamps and by fencing off the cattle from the bluffs and precipices, losses from such sources would be eliminated.

Experiments were undertaken in a scientific manner to determine what grasses would thrive under the given conditions, what were the best methods and times of seeding, and finally out of those grasses which thrived to select those which would stand grazing and would not be crowded out by native or less valuable grasses when grazed by the cattle. To determine this more than 30 different grasses and legumes were planted in small plats in three different locations under slightly different conditions. The results to date are not conclusive, but indicate roughly what is to be expected from many of these under the given conditions.

Since 1905, about 3,000 acres have been cleared of guava and lantana. After grubbing these out the land was plowed shallowly with sod plows. After such time as was necessary for the rotting of the roots the land was harrowed, then cross plowed more deeply than at first, and later still another harrowing, plowing, and another harrowing were given. Although moisture conditions were often favorable for spring planting yet it was learned that because of attacks of cutworms, it was always expedient to plant in the autumn; also that to cover the seed with a smoothing harrow very often resulted in failure, as the young plants were likely to die out if dry weather followed

soon after the seed germinated. A better plan was to harrow with a heavy spike-tooth harrow, leaving the surface in small ridges, over which the seed was then broadcasted, allowing the rains to cover the seed. By this method it was observed that even if the plants upon the ridges died out, those in the little furrows between, having the benefit of more moisture and greater protection from wind, usually survived and insured a stand.

The rainfall varies greatly in this district. It may be as low as 30 inches at some points along the coast and it may be as high as 200 inches in some years at the highest points of the hills, probably 60 inches is a fair average for the greater part of the land where the seeding has been done. It will be seen from this that conditions for growth of grasses are much better than could be found on the leeward side of any of the islands.

In addition to the 1,000 acres of buffalo grass above mentioned there were planted in the beginning about 4 acres of Para grass, 20 acres of Guinea grass, and a small area in alfalfa from which fields hay is now obtained for the mules and horses.

There were planted in 1909, 40 acres of *Paspalum dilatatum* and also 350 acres of *Agrostis vulgaris*, or redtop, and *Dactylis glomerata*, or orchard grass; in 1910, 500 acres of *P. dilatatum;* in 1911, 400 acres of *P. dilatatum* and of orchard grass mixed, using, per acre, 10 pounds of orchard grass to 5 of the Paspalum; also in 1911 about 30 acres were seeded to *P. virgatum* and *P. compressum.* This year, 1912, 400 acres will be planted to *P. dilatatum* and *P. virgatum* and Natal redtop, using 10, 3, and 2 pounds per acre, respectively.

This makes a total of about 2,700 acres which will have been seeded to tame grasses for pasture. Hereafter about 200 acres will be seeded annually until all arable land is planted, after which some of the buffalo grass will probably be replaced.

The fields are now divided into 10 paddocks and the cattle into 6 herds, which allows a period of recovery in each paddock by occasionally changing the herds to fresh pastures. The swamps have been drained and the cattle fenced from the rougher mountain lands, and in addition to the saving of losses from these sources it has been noticed that the cattle suffer less from the liver fluke than before the drainage was done. The loss of calves in 1912 was only 0.3 per cent, all of which occurred in animals under 6 weeks of age. The herd has been increased from 900 head in 1905 to 2,000, and it is evident from the looks of the pastures that a further increase of at least 75 per cent would not damage them. There are now 19 pure-bred Hereford bulls and 10 heifers of different ages, some of which were imported from Missouri, Iowa, California, Washington, and from New Zealand. This number is sufficient to furnish a home supply for breeding pur-

poses for several years. The original stock, which dresses 400 to 500 pounds at 5 or 6 years of age, is gradually being replaced by half-breed Herefords, and it is hoped that within a few years they will be able to sell animals dressing twice as much at one-half the age.

NOTES UPON VARIOUS GRASSES.

(1) It was noticed upon the newly seeded lands that the ground was first covered with kukaipua (*Syntherisma sanguinalis*), white honohono, and so-called glue bush. These annuals, the first two of which make good grazing, shade the land and protect the tame grasses from the sun and wind, thus giving them a better chance to grow. When the latter have attained some size, nothing more is seen of the former.

(2) In planting orchard grass with paspalum the former seems to grow more rapidly at first and furnish grazing much sooner than the latter, and it is more valued because of this habit.

(3) Natal redtop seems to be better for hay than for grazing, but has some value for pasture when mixed with other grasses.

(4) *Paspalum dilatatum*, *P. virgatum*, and *P. compressum* each seem to have the power to crowd out Hilo grass (*P. conjugatum*). All of them are very promising as pasture grasses and are spreading over the adjoining fields. Which of them will be the most persistent is yet to be determined.

(5) It was observed when trying to start *P. dilatatum* from roots placed in the open fields that the cattle ate it greedily, pulling it up or pawing it out before it had time to get well rooted. However, when a plat containing several finer grasses was thrown open for pasture they grazed the latter as closely as a lawn is clipped. but allowed the coarser paspalums to attain greater size.

(6) Orchard grass, creeping bent, Rhode Island bent, Kentucky blue grass, Italian rye grass, Natal redtop, *Paspalum floridum*, and other grasses which seemed to start well are very likely to be crowded out by the coarser paspalums because of this close grazing by the cattle and because of the greater vigor of the latter.

(7) Rescue grass, velvet grass, and a mesquite grass were crowded out by other grasses. Rescue did especially well in the plats at first.

(8) White clover was completely eaten up or rooted out by the cattle.

In view of the fact that in the United States all of the old cattle ranches are being transformed into smaller farms and given over to the production of field crops as well as the raising of cattle, and that the feeding of the cattle upon these farms will in the future be a more important work than the grazing of them, it is perhaps to be wondered

why at this time an owner would think of seeding down a ranch to grass and planning to raise cattle by grazing only. It is true that in Hawaii some of the ranches have followed the lead of those in the United States and have given up the cattle business and devoted the land to the culture of crops, either cane or pineapples, and that is proper since with these crops there is an assurance of greater returns per acre than with cattle; but at Hanalei there is such a heavy rainfall that a good growth of grass is at all times insured, so that with good stands of palatable tame grasses the carrying capacity of an acre is much larger than would obtain upon lands on the leeward sides of the islands or in the regions in the United States which were in the past devoted to the cattle ranches. Furthermore, a market for the beef is assured right at home upon the island of Kauai, and as such supply is necessary it is fitting that the supply of the need should be undertaken in a scientific and businesslike manner, which, it would seem from this study of methods, has been done.

Upon rougher and rocky lands such a practice would be out of the question and methods used under these conditions would be more laborious, expensive, and in the end would result in stands less perfect than is possible by the method described; and the carrying capacity of an acre could never equal that in the case given. However, the best method in which to work over rocky and rough lands is worthy of study and may be reported upon later.

REPORT OF THE SUPERINTENDENT OF THE HAWAII SUBSTATIONS.

By F. A. Clowes.

HILO SUBSTATION.

The Hilo substation comprises approximately $1\frac{3}{4}$ acres of land bordering on the farm of the Hilo Boarding School. The use of this land was granted to the experiment station by the Territorial government in December of 1910. The experiment station entered into a cooperative agreement with the Hilo Boarding School, whereby the school supplied all the unskilled labor, mules, and farm machinery for the plats and the experiment station directed the work. This arrangement has been very satisfactory and valuable work has been accomplished.

Three lines of work have been carried on, namely, experimental work with upland taro, experiments with bananas, and demonstrations of leguminous crops for feeding and green manuring.

Two taro experiments were planted and harvested during the period under report. The first was one to determine the relative value for seed of the three classes of seed or hule, namely the makua or parent hule, the oha or hule from the large lateral corms, and the puu or the small lateral hules planted entire. The other taro experiment was a fertilizer test. These two experiments covered an area of three-fourths of an acre. (The results will be published later in bulletin form.)

A plat 120 by 135 feet is devoted to a test of planting Bluefields and Hamakua bananas at distances apart of 8 by 8 feet, 10 by 10 feet, 12 by 12 feet, and 15 by 15 feet. At the time of planting there was uncertainty as to identification of the Bluefields and the Hamakua bananas. These two varieties are so similar that it was impossible to get a clear and distinctive description of each. It was the intention to plant the experiment with the Bluefields, but it was impossible to secure a sufficient number of plants that were genuine Bluefields. Sufficient Bluefields were secured, however, to plant one row across each plat of the experiment, and a sufficient number of the Hamakuas to plant another row across each plat of the experiment were secured. All the other plants used were of a mixed lot

which at the time could not be separated into Hamakua and Bluefields.

At the time of planting it was noticed that the Hamakua suckers were of a deep purplish red color at the base, while the Bluefields were of a lighter pink color. This was found to be a constant difference between the suckers of the two varieties. The Hamakua always tends to have a dark red color on the stalk below the ground, while the Bluefields is of a light pink color. Another readily noticeable difference is that the midrib of the Hamakua leaf is green, with little if any tendency to pink color, while the Bluefields has a decided pink or red color to the midrib. This difference is particularly noticeable in the suckers of the two varieties. Moreover, the Bluefields are about 1 foot taller.

The bananas in this experiment, having been planted in June, 1911, are not yet matured. The results are, therefore, not yet available.

Small plats of soy beans, cowpeas, pigeon peas, jack beans, velvet beans, and alfalfa are grown in order to demonstrate to stock raisers of the surrounding region the crops which could be profitably grown to supplant grain in cattle rations.

GLENWOOD SUBSTATION.

The Glenwood Experiment Farm (Olaa substation), consists of 16½ acres of land situated on the Volcano Road at Glenwood. The elevation above the sea is 2,300 feet. The land has a good slope to the southeast. The soil is deep and with the exception of a small area has good natural drainage. The buildings, which were erected previous to July 1, 1911, are a superintendent's cottage, and a farm building containing office, storeroom, workroom, men's dormitory, horse stable, implement shed, and tool rooms. There have since been added to this equipment a cow stable to accommodate four cows, and a building 14 by 18 feet for dairy purposes. The equipment for this is now ordered, and consists of a 3-horsepower steam boiler, a 1-horsepower steam engine, turbine Babcock tester, combined churn and butter worker, and the necessary utensils and accessories for the production of first-grade farm creamery butter. A power separator has been donated by Mr. B. F. Dillingham.

Tributary to this experiment farm is a large area of apparently good land, much of which is public property available for homesteading purposes. A considerable area of privately owned land has been cleared of the heavy growth of ohia forest that originally covered it. At one time there were extensive coffee plantations laid out here, but after the first crop further profitable crops were not obtained. Following the coffee, much of the land was planted to sugar cane. The results with this crop have almost uniformly been that only first cuttings were profitable, the ratoons almost always proving financial

failures. Tobacco was at one time successfully grown, but the settlers who raised it were unable to secure a market, and had to give up their homesteads and seek a living elsewhere. At present much of the cleared land is under lease to ranchers and is affording pasture for range animals. A promising butter business has survived the agricultural misfortune of this region and one grower is raising easter lilies and pohas (*Physalis peruviana*) with fair success.

There are evidences of extensive agricultural work in this region in the days of abounding native population. The native bananas (mauli type) are found growing in extensive plantations, olena (*Curcuma longa*), mamake (*Pepturus albidus*), loulu (*Pritchardia gaudichaudii*), taro, and sweet potatoes are among the plants found growing in what would otherwise seem to be primeval forest, but in reality bears clear evidence of extensive prehistoric agriculture.

The rainfall in this region is in the neighborhood of 200 inches a year. The elevation is such that there are comparatively few days without a fall of rain. This makes field work disagreeable and renders the soil sticky. Unless great care is exercised, attempts to carry on horse cultivation serve only to puddle the soil and to produce a hardpan that is impervious to water. The tramping of the cattle in the pastures renders the surface so impervious to water that except in dry weather the surface soil is always in a condition of saturation. The soil temperatures are low, and on account of the elevation the air is cool. Plant growth is very slow. Cutworms and slugs are abundant, and the prevention of their ravages constitutes one of the big problems of the region. The moist conditions favor the presence of plant diseases. The saturation of the soil with water precludes oxidation, and the seepage of soluble plant food renders the soil lacking in plant food in quantities that would produce the most profitable crops without frequent application of fertilizers. The lack of air and the unoxidized and poisonous nature of the subsoil retards the downward progress of roots. Hence what would, from its friability and freedom from stones, seem to be a very deep soil is in reality a very shallow one.

This brief description will serve to illustrate the practical problems for the solution of which the Glenwood Experiment Farm was established.

The dairy business in this region depends at present upon extensive cheap pasture and an abundance of wild honohono (*Commelina nudiflora*) for soiling purposes. It does not rest upon a permanent foundation. Cattle thrive in this region, and the country seems to be adaptable to the live-stock industry. It has seemed wise, therefore, to devote considerable effort toward establishing the permanence of the dairy and live-stock industries. Much space and time are given to experiments on fodder crops. It is also intended to operate a

small farm creamery for experimental and educational purposes, in the hope of establishing the market end of the business upon a firm basis.

Besides the dairy work in its two branches, experiments are in progress with a great variety of market crops. A study is also being made of methods of cultivation, soil treatment, and drainage. Fertilizers are also being tried out with the aim of determining the requirements of the various crops upon these soils. A demonstration and experimental wood lot is also being planted.

Much of the time during the past year has been devoted to the rough work of removing stumps and otherwise preparing the land for systematic experimenting. Small plantings have been made of various crops at all months of the year with the idea of studying the effect of unseasonable plantings and also to find crops which gave sufficient promise to justify larger plantings. In the further development of these trials there have been planted the following forage crops:

Para grass, one-half acre; Japanese cane, one-half acre; honohono or commelina, one-half acre; corn and sorghums, 1½ acres; (of these 40 varieties are under trial); dwarf Essex rape, one-fourth acre. In addition the following have been planted: Broom corn, one-fourth acre; sugar cane for milling, one-half acre (four varieties); and pohas or ground cherries, one-fourth acre. These last grow wild in this region and the fruit sells readily as a canning crop. It is desired to determine if they can be cultivated profitably. There is also about a quarter of an acre devoted to variety and fertilizer tests on vegetables and flowers. Of these the following have given results which are believed to warrant the planting of larger areas: Cabbages, cauliflower, strawberries, Easter lilies, cucumbers, pole beans, rutabagas, and kohl-rabi.

Preparations have been made to plant about a quarter of an acre of cooking bananas.

Other crops which have given promise as forage are field peas and oats. It is intended to plant these on a larger scale. Small trials are being made of grasses (20 varieties), clovers (11 kinds), vetches, oats, flax, buckwheat, spelt, emmer, wheat, millet, peppermint, ginger, *Canna edulis*, awa, asparagus, potatoes, sweet potatoes, and bananas (8 varieties).

In the woodlot plantings of all the trees commonly grown for such purposes throughout the Territory have been made. Others will be tried later.

Other trees and shrubs planted are apples, walnuts, camphor, Chinese oil-nut tree, rose apple, and mammee apple.

The fertilizer work is incomplete. Enough, however, has been accomplished to show that even on new land fertilizer gives decided

beneficial results. Stable manure has given better results than applications of complete high-grade commercial fertilizer. On abandoned cane land that had been used for pasture for several years 500 pounds of complete high-grade fertilizer was needed to produce even a fair crop of corn. It is evident that heavy fertilization is needed, and apparently this should be applied as often as once every three months.

Acknowledgment is made of the many kindnesses of the business men of Hilo, the officials of the Olaa Sugar Co., and many others who have shown interest and given much help in the work of equipping and establishing this substation.

REPORT OF THE SUPERINTENDENT OF THE RUBBER SUBSTATION.

By W. A. Anderson.

TAPPING CEARA RUBBER.

The Ceara tapping on the Nahiku plantations has been directed chiefly toward the development of a system of tapping that would yield the largest amount of rubber per unit of labor without injury to the tree, and curing the product in such a way as to make it satisfactory to the manufacturers.

Many methods which would give profitable results in most tropical countries with their cheap labor, were found to be impracticable here with labor at approximately $1 per day. No satisfactory incision method for tapping the Ceara tree without removing the outer bark has so far been found. At the same time, aside from the expense involved, the injury which results from the frequent stripping of the entire outer bark makes this undesirable.

In July, 1911, after a considerable amount of experimenting, tapping on a commercial scale was started by removing the bark to a height of about 18 inches and pricking with a wheel pricker making pointlike incisions, run vertically, on four sides of the tree at each tapping. The latex was allowed to run to the ground and left there until the following day when it was coagulated. The rubber was then collected, in a very dirty state, washed with a single macerator, vacuum dried, hung in the air for one to two weeks, and then shipped. The average yield per day's labor involved in preparing the trees, removing the bark, tapping, and collecting, on 5-year-old trees, on 70 acres, in two months, was approximately 2 pounds of washed rubber. It was found that after two weeks of tapping daily, the yield fell off to such an extent as to indicate the suspension of tapping.

On trying to resume operations after a rest of two weeks, it was found that the flow of latex was hindered by the new outer bark, that was forming a scaly, powdery covering which gradually became thicker and tougher, preventing the flow so that this form of incision could no longer be profitably made without stripping the bark again. Experiments in removing the bark on the 18 inches next higher up showed that too little latex reached the ground and that which remained on the tree could not be readily collected. Jabbing with a flat knife blade, making a horizontal incision on this newly

stripped area, gave a better flow of latex, but the expense of collecting proved this impracticable, both with and without a previous application of acetic acid.

These experiments, however, demonstrated two fundamental facts: First, that a knife jab made horizontally gives better results than one made vertically; second, that the portion of the tree just above the ground, to a height of about 6 inches, yields rubber in much larger quantities than any other portion. This area is never tapped when collecting cups are used, as the spout is necessarily inserted high enough to conduct the latex to the cup, set on the ground, and the tapped area is all above the spout, and, consequently, above the most prolific section of the tree.

The second of these facts was utilized in the development of a system which has undoubtedly given better results in proportion to the labor involved than any other. By this method, the bark is removed to a height of about 6 inches and cuts made with a very thin knife blade from the ground to the top of this stripped surface. The latex is allowed to flow to the ground and coagulate. The following day the rubber is collected and new cuts made at the same time.

The advantages are obvious. Only the richest portion of the tree is utilized, and at the same time, the portion where injuries heal most quickly After the first cutting, the collecting and cutting are performed at the same time, thus saving one-half of the walking that would be necessary in passing from one tree to another if there were separate operations. The cutting knife is used to facilitate the removal of the rubber from the soil in collecting, so that there is no time lost in changing tools. The laborer carries his bucket in one hand and his knife in the other, sets the bucket down, naturally nearest the hand that is freed, slips the knife under the lump of coagulated rubber, on the ground, lifts the rubber with the free hand, aided by the knife, deposits it in the bucket, and makes his new cut in the tree with the knife in the other hand, lifts the bucket with the free hand and passes on. It would seem that the number of motions involved is reduced to a minimum. The largest amount of rubber collected in this way, by one man in one day of 10 hours' tapping and collecting, is 9 pounds of washed rubber, though the average yield for 100 acres during six months' tapping is somewhat less than 4 pounds.

The disadvantages lie chiefly in the fact that so small a portion of the tree is tapped. The yield per tree at each tapping is small, in some cases 1 pound of washed rubber to 400 trees. The number of tappings possible per year, as indicated by a six months' trial, is about 48, with two strippings per year. The removal of bark appears to be less injurious on this area than higher up, and it is probable that the trees would stand this removal. Each stripping

after the first is more difficult, as the cuts make the renewed bark very rough and it breaks off in small patches instead of coming off as one sheet, as is the case with the first stripping. If the cut is made properly it heals without a ridge and more quickly here than elsewhere on the tree. Attempts to continue this method higher up on the tree have not so far proven successful.

Having thus found approximately the maximum yield per day's work, attention was directed toward increasing the yield per tree, with a view to getting a proper adjustment between these two, which will be the point of diminishing returns. As satisfactory results were not obtained by continuing to remove the bark in horizontal strips, vertical strips were tried. First, a strip about one-third inch wide was removed with a broad, U-shaped knife, gauged to remove only the outer bark, exposing the inner bark for incision. The incisions were made with a blade of the same width as the stripped surface, at regular intervals, along the length of the strip. In this way the yield per tree per tapping was increased, but too large a portion of the rubber remained on the tree as scrap, which could not be profitably collected. The application of a solution of acetic acid caused practically all the latex to coagulate on the tree, where it was collected to better advantage. To widen the stripped surface, a second cut was made 1 inch or more from the first, and the bark between these two cuts was removed. This is done quickly and simply. The wider strip is treated with acetic acid and incisions made at intervals of about 2 inches, with a blade 1 inch wide, so sharpened as to touch the cambium at only two points instead of along the entire edge. The rubber is collected one hour after tapping.

The experiment is not yet completed, only one week's tapping having been done. It is found, however, that one man can make the incisions as fast as two men can collect, and the three men in one day can incise and collect from about 800 trees exclusive of stripping, securing about 1 pound of washed rubber to 70 trees. Four tappings can be made on each strip before exposing a new surface. Including stripping and all labor, results for the week were at the rate of $2\frac{2}{3}$ pounds per day's work.

For the purpose of comparing this method with the one previously described, which gave the maximum yield per day's work, we may call the former method A and this one B. Calling the average yield per day's work in A 4 pounds, and the average yield per tree one three-hundredths pound, we get 4 pounds from 1,200 trees in one day's work. In B we get $2\frac{2}{3}$ pounds from 186 trees in one day's work. It is obvious that were the number of trees available unlimited, A would be the better method. Since on any plantation, however, the number of trees is necessarily limited, the total profit on labor from a given number of trees will determine the relative value of the two

methods. From 50,000 trees A would give 167 pounds in 41⅔ days' work. At $1 per day and $1 per pound (the approximate present values), profit on labor would be $125.33. B would give 683.4 pounds for 268.8 days' work, leaving a profit on labor of $414.60 from the same number of trees, from which it appears that B is the more profitable plantation method so long at least as the value per pound of rubber remains greater than one-half the cost of a day's work.

This tapping was done in the last week of June. It is probable that better results can be obtained during the latter half of the year, as the trees are not in full leaf before the middle of July.

CURING AND MARKETING CEARA RUBBER.

The rubber obtained was shipped direct to manufacturers in New York. The first shipment, vacuum dried, was valued at 10 per cent below the best Para and sold on that basis. Two later shipments, treated like the first in every way, but not vacuum dried, were valued over 25 per cent below Plantation Pale Crepe. While the last shipment from which returns have been made, partly vacuum dried, was sold at 10 per cent below Ceylon Fine Pale Crepe, and brought $1.15 per pound. The rubber is now all being vacuum dried and pressed while still warm from the dryer into sheets about 2 inches thick, 10 inches wide, and 3 feet long, weighing approximately 20 pounds each. The loss in washing and drying rubber thus prepared has been found to be 2½ per cent.

The conclusions from the work so far done are that tapping method A is the cheapest and most desirable where the trees to be tapped would furnish work for all the labor available, but method B gives greater profit from a given number of trees, and that either method can be carried on commercially at a profit under present conditions. The product, though very unattractive as it comes from the field, is capable of being turned into rubber of the first class without too great expense.

Contemplated experiments on a commercial scale to determine the effect of fertilizers on the yield of latex have not been carried out, but it is hoped that some work of this sort can be done in 1912.

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Issued February 20, 1915.

HAWAII AGRICULTURAL EXPERIMENT STATION,
E. V. WILCOX, Special Agent in Charge.

REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION.

1914.

UNDER THE SUPERVISION OF
OFFICE OF EXPERIMENT STATIONS,
U. S. DEPARTMENT OF AGRICULTURE.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1915.

HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU.

[Under the supervision of A. C. TRUE, Director of the Office of Experiment Stations, United States Department of Agriculture.]

WALTER H. EVANS, *Chief of Division of Insular Stations, Office of Experiment Stations.*

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LETTER OF TRANSMITTAL.

HAWAII AGRICULTURAL EXPERIMENT STATION,
Honolulu, Hawaii, July 30, 1914.

SIR: I have the honor to transmit herewith and to recommend for publication a report of the Hawaii Agricultural Experiment Station, 1914.

Respectfully,

E. V. WILCOX,
Special Agent in Charge.

Dr. A. C. TRUE,
Director Office of Experiment Stations,
U. S. Department of Agriculture, Washington, D. C.

Publication recommended.
A. C. TRUE, *Director.*

Publication authorized.
D. F. HOUSTON,
Secretary of Agriculture.

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REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION, 1914.

SUMMARY OF INVESTIGATIONS.

By E. V. Wilcox, *Special Agent in Charge.*

BUILDINGS AND GROUNDS.

The glass propagation house which was erected for use in propagating delicate cuttings and seeds was originally fitted with a water tank on one side which was covered with glass. This was intended as a sun heater, the water circulating through pipes under the propagation beds and connected with the tank on the outside. It proved unsatisfactory, however, and a rearrangement was made by which a gasoline heater was sunk into the ground alongside of the propagating house. This arrangement has given satisfactory results.

The sedge commonly known as Japanese nut grass (*Cyperus rotundus*) has become generally distributed throughout Hawaii and has proved to be a most difficult weed to eradicate. Several patches of it have become established on the station grounds, in fact it is practically impossible to prevent its accidental introduction through seeds carried by animals or on the shoes of visitors. The remarkable quickness with which the nut grass springs up after hoeing makes it an unusually serious pest in all cultivated fields except in the case of tall crops like cane or pigeon peas which ultimately shade the nut grass out. The apparent destruction of the nut grass by this means, however, is a delusion, for as soon as the crop is harvested the nut grass begins again unabated. The only method by which this pest has been successfully controlled thus far is that of mowing at intervals sufficiently frequent to prevent the weed from forming seeds. If this practice be persisted in for a sufficient length of time, the underground bulbs become exhausted and the plants die. This method, however, is not applicable in cultivated fields. A series of experiments has therefore been devised to test various methods of eradication, such as hoeing, harrowing, cutting, and spraying with arsenite of soda at intervals so timed as to prevent the weed from seeding. It is hoped in this way to find a practical method by which the further spread of nut grass can be prevented.

About 7 acres of land adjoining the station grounds and belonging to the Public Health and Marine Hospital Service were turned over to the station for agricultural use for an indefinite period. Not all of this area has soil adapted to agricultural purposes. The whole tract has been fenced and about 5 acres of land cleared ready for plowing. It may not be possible to put water for irrigation purposes on this land, but the rainfall during the autumn and winter is sufficient for the growth of winter crops of garden vegetables, cereals, and other crops which it is hoped to test out during the coming year.

One of the chief needs of the station at the present time is a tract of uniform soil which can be devoted to permanent plats for experiments with fertilizers and a rational system of rotation. The need of such a set of plats has become more and more urgent. The present location of the station was poorly chosen in so far as prospects for scientific fertilizer tests are concerned. The soil is conspicuously lacking in uniformity. The physical and chemical nature of the soil changes every few rods and the patchiness of the soil on the station grounds as a whole is one of its most obvious features. Outside of pot experiments, the fertilizer experiments of the station have been made on the substations and by cooperative arrangements with pineapple growers who happen to possess large tracts of uniform soil. No matter how smoothly, however, a cooperative experiment may be operated, it suffers from the great disadvantage that it can not be permanent nor extend over a sufficiently long period. A tract of land which would be well adapted to the purposes of permanent fertilizer experiments lies near the town of Wahiawa and within the army reservation of Schofield Barracks. This tract is separated by a gulch from the remainder of the reservation and could, therefore, not be used by the Army for maneuvering. It is hoped that an arrangement may be effected by which the station can secure the use of this land permanently for agricultural purposes. A series of experiments could then be organized and carried on in a systematic manner so that the effects of certain fertilizer applications and certain systems of rotation would be permanently on exhibit as an evidence of the scientific value of the fertilizer experiments undertaken, and of the practical value of the system thus adopted for the use of the surrounding pineapple growers and other farmers. The experiments now in progress on a small tract of land on Wyllie Street, leased by the station, indicate that the results thus far obtained in comparing aeration and nonaeration of the soil between crops of rice are rendered somewhat doubtful by the lack of uniformity of the soil. This tract therefore can not be used for the purpose in question, but must be devoted to other work where uniformity of the soil is not of so much importance.

The growth of the station has brought about the urgent need of another building of about the size and proportions of the present office building. The present office building is needed exclusively for office, library, mailing room, and storage of bulletins. The quarters of the entomologist are at present in the office building. The building in which the departments of agronomy and chemistry are now housed is all needed for the chemical department. The horticultural department occupies a small building not well adapted to the work of the department. A new building of the size of the present office building would furnish room for the departments of agronomy, horticulture, and entomology for a number of years to come.

CHANGES IN THE STAFF.

D. T. Fullaway, at the request of the Bureau of Agriculture of the Philippines, was furloughed for work in connection with that institution from October 15, 1913, to February 28, 1914. He was again furloughed on June 1, 1914, for a period of one year to search for parasites of the Mediterranean fruit fly, under the auspices of the Territorial Board of Agriculture and Forestry. J. E. Higgins was absent on furlough during the whole year for work in connection with the University of Porto Rico. C. K. McClelland resigned to accept a position as agronomist at the Georgia Experiment Station. It is proposed for the present at least to have the assistant agronomist continue the work of that department under the direction of the chemical department in order to affiliate more closely the work along those two lines. A plant pathologist is greatly needed at the station. The funds which have thus far been available were not sufficient to make possible the employment of a man for this purpose. There are a number of plant diseases in Hawaii which need investigation. Prominent among such diseases are a banana disease of unknown nature, anthracnose of mango and avocado, and a blight of potatoes.

SUBSTATIONS.

The problem of greatest importance at the Glenwood substation is that of producing suitable forage and other feeding stuffs for dairy cows. The large tract of land devoted to dairying in the neighborhood of the substation presents some peculiar difficulties which must be overcome. The general peculiarity of the neighborhood is the excessive rainfall, which ranges from 200 to 350 inches per year. Occasionally there are years in which there are not more than 20 days in which heavy rainfall does not occur. Many of the legumes apparently can not be made to thrive under these conditions. The same may be said of certain grasses and other forage plants. It is of course impossible to produce hay under such conditions without

an apparatus for artificial drying. The only possible means of storing feed is a silo. A silo has been erected at the substation and a number of experiments have already been made with the different crops for silage. The making of cane silage has offered no more difficulties than are to be met with corn silage, and cane silage of excellent flavor and well liked by cows has been made. The whole sugar cane, including stem and leaves, may be ensiled, or merely the cane tops. No unfavorable fermentation has been found to take place if the silage is properly packed. The acid in sugar-cane silage at the end of three months was found to be only 0.2 per cent. Excellent results were also had with sorghum and Para grass as silage plants. As a soiling crop, honohono (*Commelina nudiflora*) has come into great prominence. This plant grows wild throughout the Glenwood section and ratoons readily, giving heavy crops in succession, particularly if a top-dressing of manure is added from time to time after cutting.

The pure-bred Guernseys purchased for the substation have given a good account of themselves. The registered bull has been much used for service among the cows of neighboring dairymen with the result that there are now 15 grade heifer Guernseys sired by the substation bull.

The creamery work of the Glenwood substation has been reorganized on a slightly different plan from that which prevailed last year. It was found unsatisfactory to ship milk from Hilo and other distant sections to the substation creamery. The cream showed too high a percentage of acid. While the number of cows in the neighborhood is gradually increasing, there are not enough at present to make practicable a cooperative creamery run by the dairymen themselves. The essential features of the association already formed have been retained in the present organization under the title of the Hawaii Butter Makers' Association. Such members of the association as live at too great a distance from the creamery now make their own butter. The milk from the dairies in the immediate vicinity of the substation creamery is separated and butter made for the actual cost of the operation. All of the butter made at the substation creamery and by all other members of the association living at a distance from the creamery is sold by the secretary of the Butter Makers' Association. This butter has made a satisfactory place for itself on the market in Hilo and in Honolulu.

The Glenwood substation is also carrying on experiments with poultry and ducks. A flock of Rhode Island Red chickens is maintained at the station as a general purpose breed, and White Leghorns are raised for egg production. The system of deep litter brooders is used with pronounced success.

At the Hilo substation experiments with bananas and taro have been continued. A study of the varieties of taro of most economic importance has been made and descriptions are being prepared. This material, together with results of experiments in various methods of propagating taro, various distances of planting, and the use of various fertilizers will be ready for publication as a taro bulletin during the coming year.

The work at the Waipio substation is of a cooperative nature. The main problem for the year was a study of onion production. Red and white Bermuda onion seed was planted directly in drills in the fields on September 23, October 3, October 9, November 13, and December 10. Part of the seed was planted in shallow furrows and part in level culture. The Waipio substation is in a region of low rainfall, but unusually heavy rains occurred this year, filling the furrows with soil and burying the onion bulbs. Considerable thinning and transplanting had to be done throughout this area, and the bulbs buried by washed soil had to be uncovered. The best results were obtained from the sowings in September and October. November and December appear to be too late. Areas on which trash was burned not only produced larger onions, but the onions required only 90 to 100 days from seeding to maturity, as compared with 130 to 160 days on areas not burned. It is planned to carry on some experiments to determine whether it may be economical to heat the soil in the rows by means of a crude-oil blast before planting. The area planted to onions was 8 acres. Most of the soil showed 3 per cent manganese by analysis. From seeding to harvest 23 inches of rain fell. The 8 acres of onions yielded 32,210 pounds, not counting the small onions of pickling size.

At the Nahiku substation the most important result obtained during the year was the demonstration that by means of cuttings from heavy yielding trees, a whole plantation of rubber can easily be obtained with a yield approximately that of the most prolific trees. In the experiments carried out in Nahiku, whole trees of *Manihot glaziovii* of known high yield were sawed into cuttings three or four feet long and planted in the wet soil. The cuttings take root and begin growth very promptly, whatever may be the size of the cuttings. Some of them were 5 inches in diameter.

The roselle experiment was continued during the year with the result that higher yields were obtained than had ever been reported for roselle, approximately 17,000 pounds of fresh fruit per acre. A drying plant has been erected for preparing the material promptly for shipment. Two hundred acres of roselle are now growing, and from the present condition of the plants it is to be expected that a large yield will be obtained at the next picking.

A 10-acre fertilizer experiment on Ceara rubber was carried out during the year. The results of this experiment while interesting are not sufficiently pronounced to warrant the conclusion that fertilizers would pay when applied to rubber in the Nahiku district. The best results both in yield of latex and in growth of trees were obtained from the use of superphosphate and potassium sulphate, without the addition of nitrogen in any form. The soils in question are rich in humus and nitrogen.

At the Homestead substation particular attention was given to the relative economy and profits to be obtained from the growing of various crops, including sugar cane, pineapples, peanuts, field corn, and sugar corn. The results obtained indicated that pineapples yielded the greatest profit, followed by sugar cane and sweet corn. The relative economy from these crops, however, varies from year to year on account of the irregularity in prices. At present the prices offered by the canneries for pineapples are less than the cost of production.

COOPERATION WITH MILITARY POSTS.

During the year the amount of cooperation with military posts has greatly increased. For the most part new work in grading and street making at the Army and Navy posts has made it necessary to secure large quantities of ornamental plants and fruit trees in order to overcome the barren appearance of the new grounds. Along this line of work the station staff has furnished plans, general advice, and a large amount of material for planting. At Schofield Barracks a rather elaborate farming experiment is in progress in cooperation with the station. About 60 acres of land have been planted in legumes, Sudan grass, sorghum, Japanese cane, and other forage plants for the purpose of furnishing green feed for Army mules and horses. As a result of the favorable outcome of this experiment it is likely that the authorities at Schofield Barracks will extend their farm operations for the coming year. The United States Army is one of the largest factors in Hawaii in bringing about the greater development of diversified farming. The Army already uses algaroba meal as a part of its mule and horse ration and will take corn as another portion of the ration as soon as it is produced in sufficient quantities. The Army contracts call for 28,000 pounds of onions per month and 240,000 pounds of potatoes per month. During the past year onions were supplied from local sources for two months only, but potatoes not at all. The Army purchased outside of contract large quantities of eggs, poultry, and miscellaneous farm produce. The military authorities are desirous of having the Territory develop a completely independent source of food supply.

MARKETING DIVISION.

At the 1913 session of the Territorial legislature an act was passed providing funds for this station to be used in furthering the marketing of miscellaneous agricultural crops. The Territorial marketing division was established under the supervision of the station on July 1, 1913. The produce sent in by farmers has increased during the year from $84 to nearly $6,000 per month. The total value of produce received and handled by the marketing division during the year amounts to $26,500, at a cost of $2,000.

The effect of the establishment of the marketing division is apparent throughout the Territory in the greatly increased interest in diversified farming. Heretofore most of the ordinary farm produce consumed in the Territory has been imported. There were only a few farmers who were raising miscellaneous produce, and the small quantity of produce which they raised was totally insufficient to furnish a uniform and satisfactory supply. Dealers in Honolulu, therefore, depended upon the mainland supply. Moreover, the price obtained by farmers for their produce was not sufficient to encourage general agriculture. So unsatisfactory a state of affairs had arisen that the most practical question was not how can a crop be grown, but can it be marketed. The chaotic state of the Honolulu market and high freight rates made it impossible for the farmer to raise miscellaneous produce at a profit.

As a result of the establishment of the marketing division various lines of farming have been developed with profitable results. The shipment of produce from all parts of the Territory to one central market insures a large enough quantity of each kind of produce to occupy a place in the market, and also insures a fairly uniform and constant supply. These conditions having been met, the interest shown in local produce by Army posts, hotels, boarding houses, schools, and other institutions, as well as wholesale dealers, has been gratifying.

The effect of the market has been perhaps most noticeable in the poultry industry. Nearly all farmers who have been interested in this line of work have increased their equipment and the size of their flocks and are prepared to be in a position to supply the demand for eggs and poultry in the Honolulu market. The marketing division issues weekly quotation sheets of the prices which have prevailed during the week on all local produce. These sheets are sent to all interested farmers and to the newspapers of the Territory. Blank forms are also sent out to interested farmers on which they can give the market information as to the amount of various crops planted, when planted, and approximately the quantity and probable time of delivery of the crop to the market. This enables the marketing

division to arrange for sales of produce in advance and thus facilitate the prompt handling of the crop. A list of breeders of pure-bred stock is kept, by means of which farmers can be placed in communication with such breeders and secure breeding stock when it is desired.

The work of the marketing division for its first year indicates two directions in which further development is needed. A branch office is required in San Francisco to handle shipments of fresh pineapples, bananas, coffee, sweet potatoes, onions, beans, kukui nuts, coconuts, and the surplus of any other produce which may be raised in Hawaii. At present the business of growing pineapples in so far as the small independent growers are concerned is almost hopeless. The cost of producing pineapples ranges from $12 to $15 a ton. The price offered by the canners at present ranges from $5 to $11 per ton for first-grade pineapples and one-half those prices for second grade. The only hope for the small grower, therefore, until these conditions are rectified, is to find a good market for his fresh fruit on the mainland. The business of shipping fresh fruit can not be carried on satisfactorily without organization. It has been tried by the pineapple growers too many times with disastrous results. If all fresh pineapples were shipped under the direction of a central office in San Francisco, as a branch office of the marketing division, it would be easily possible to prevent a regular succession of bare and flooded markets which have characterized the previous condition of pineapple shipments. Similarly with other produce, a branch office of the Territorial marketing division in San Francisco could create and supply a much larger market for local produce than is now in sight.

Another direction in which the work of the marketing division could profitably be extended is in the line of a retail department. If a cooperative store were established in Honolulu, the farmers of the Territory would be glad to furnish their produce to this store through the marketing division in order to secure for themselves a regular sale of their produce at a reasonable profit, and to secure to consumers the possibility of a constant supply of local produce at reasonable prices.

CHEMICAL INVESTIGATIONS.

The effects of heat were studied on twelve different soils of varying types, the soils being heated to 100 and 250° C. and to ignition. On the whole the effect of applying heat to soils was to render plant food compounds and other chemical compounds more soluble. The most important effects of heating soils are apparently included in the processes of flocculation, oxidation, double decomposition, and alteration of soil elements. There was a slight loss of total nitrogen from heating. One of the striking effects was the unusually rapid formation of ammonia after the soil had been heated. Heating soils

seems to bring about rapidly the effects which are otherwise obtained more slowly by aeration. It has been noted in the case of all plants with which experiments have been made that growth is much more rapid on heated than on unheated soils.

Further experiments on the fertilization of rice substantiated the results already obtained along this line. In nearly all of the rice soils of Hawaii ammonium sulphate or some form of organic nitrogen seems to be the fertilizer most needed. Poor growth results from the use of nitrate as a source of nitrogen for rice. Experiments to determine the possible effect of aeration of the soil between rice crops indicated some advantage from aeration, but the experiments were inconclusive on account of the lack of soil uniformity in the experimental plats.

The investigation of the nature of nitrogen compounds in the soil has been continued and the subject studied from various standpoints. The results thus far obtained indicate that bacteria cause more rapid decomposition of the diamino acids than of the other groups present in protein. A further study of this subject is being made on pure proteins. The hydrolytic and other decomposition products of proteins will receive further study.

Attention has been devoted also to a study of the physical properties of soils with interesting results. In heavy clay soils all fertilizers used alone or in mixtures at the ordinary rate have been found to check the movement of soil moisture. Sodium nitrate increased the water-holding power of soils and also increased the rate of percolation of the water. Corresponding with this there was a diminution of the capillary rise of moisture. Capillarity was found to be greatest in silty soils, less in sandy soils, and least in heavy clay soils. In all these experiments the increase in the concentration of the fertilizer salts caused a diminution in the capillary movement of water. In ordinary soils all fertilizers diminished the percolation of water through the soils. Lime and magnesia salts checked percolation less than the salts of sodium, potassium, and ammonium. In clay soils chlorids were found to check the flow of water less than sulphates, while the reverse proved to be true in the case of organic soils. In each case the soil which showed greatest capillarity offered the greatest resistance to the percolation of water. It was demonstrated that fertilizers exert physical effects which are perhaps more easily detected and measured than are chemical effects.

In a study of the function of fertilizers in soils it was found that phosphoric acid was fixed to a greater extent than other fertilizers. This fertilizer proved most effective when applied in the most soluble form. While, however, phosphoric acid in soluble form was fixed in the soil to an almost indefinite extent in so far as leaching is concerned, it still remained readily available to plants, as shown by the

decided residual effect of phosphoric acid upon three successive crops grown without additional application of phosphoric acid. Ammonia was fixed to a greater extent than potash, but was less firmly held by the soil, and may become available more promptly. Nitrates were not fixed by Hawaiian soils to any appreciable extent. It was found that there was less loss by fixation in the soils when fertilizers were applied singly than when applied in combination. More deflocculation took place, however, when fertilizers were applied singly.

Continued study of the lime-magnesia ratio in Hawaiian soils brought additional evidence that this ratio is not important in itself. It becomes important only when soluble salts are in great excess or when the soil solution is greatly concentrated and the mineral matters out of normal proportion.

Additional evidence has been accumulated that attention to aeration is especially necessary for the proper growth of plants in Hawaiian soils. No nitrification took place without aeration. In soils which have been left fallow for a year or more there was practically no nitrate nitrogen, but nitrification took place rapidly as soon as the soils were thoroughly tilled.

Volatile antiseptics and heat were found to increase ammonification for a period of two weeks. Nitrification then began after about three weeks, and gradually increased to a maximum. Volatile antiseptics in experiments at the station did not kill protozoa, but these organisms were easily killed by heat. The evidence accumulated in soil work at the station is against the possibility of protozoa being connected with nitrification in soils.

Continued pot experiments with various forms of phosphate have demonstrated anew that soluble phosphates do not leach through the soils, but remain permanently available for plant growth. It was also shown that legumes used as green manure greatly increased the availability of rock phosphate.

Analyses were made of all the common tropical fruits in Hawaii. A special study was made of the changes which take place during the ripening of bananas and papayas. A study was also made of the organic phosphorus of rice. This is of particular importance on account of the extensive use of rice as food. The organic phosphorus compound was found to be formed chiefly in the bran or outer layer of the rice grain.

HORTICULTURAL INVESTIGATIONS.

The attempt to establish a strain of papaya with self-fertile flowers and with male trees eliminated has been continued. The results give promise of complete success within two or three more generations of papaya. The examination of 454 trees of the second generation

of breeding showed that 95⅓ per cent of these trees are fruit bearing trees with perfect flowers. Two male trees were cut off 3 feet from the ground and when the new branches came out it was found that the sex had been changed and that regular, perfect flowers, each bearing fruit, were developed.

From the orchard records kept at the station interesting data are now available regarding the average age at which budded, inarched and seedling mangoes and avocados have come to bearing.

On account of the prevalence of the Mediterranean fruit fly it was found necessary to bag some of the fruit which was needed for experimental purposes. Ordinary paper bags were used for this purpose and proved to be a cheap and efficient means of protecting the fruit.

The local interest in hibiscus continues unabated. A number of new varieties have been originated at the station since the publication of Bulletin 29. Perhaps the most interesting ones are two yellow-flowered varieties originated by self-pollination from pink varieties and a semidouble white. Many worthy varieties have also been produced by private breeders and the types have been sent to the station for description. The pink cotton bollworm has been found to breed quite freely in the pods of those varieties of hibiscus which form seed.

A nearly spineless cactus, supposed to have been introduced into Hawaii by Don Marin, has been grown at the station for several years. An opportunity offered to test the hardiness of this cactus in comparison with a number of other drought-resisting plants and several varieties of Burbank's cactus. All of these plants were set out on the island of Kahoolawe in an excessively dry region somewhat exposed to wind. At the end of six months the place was visited again when it was found that none of the plants had grown except the Marin cactus which was growing satisfactorily. In the few tests which the station has been able to make, this cactus, under dry conditions, has grown about three times as fast as the Burbank varieties.

AGRONOMICAL INVESTIGATIONS.

A variety of Japanese rice known as Bezembo was obtained from James Armstrong, of Pearl City. This variety yielded about the same as the other varieties of Japanese rice with which the station has experimented, but matured about 10 days earlier. Experiments will be continued under more favorable conditions to determine definitely whether the æration of the soil between rice crops is of benefit or not to the growth of rice.

Year by year tests are carried on with various cereals in order to determine what kinds fit in with the agricultural program of Hawaii and what varieties can be recommended for Hawaiian conditions. At low altitudes wheat seems to offer no promise. Rye, oats, and certain varieties of barley make a more satisfactory growth. There is a tendency in barley, however, to stool excessively without forming seed heads. Considerable difficulty has been experienced in carrying African sorghums to successful seeding. Seed eating birds are so numerous that it is impossible to save the seed on sorghum plats without bagging the heads. The heads, however, do not develop quite normally under bags.

Among the numerous grasses which have been tried at the station, Sudan grass and Giant Bermuda grass have perhaps attracted most attention. Sudan grass grows rapidly and produces a heavy yield wherever it has been tried in Hawaii except at high elevations. The greatest growth of this grass was obtained on Molokai, where it reached a height of $10\frac{1}{2}$ feet in 70 days. It ratoons promptly and satisfactorily wherever it has been tried. Giant Bermuda grows with unusual rapidity and gives promise of being a valuable pasture grass. Teff grass (*Eragrostis abyssinica*) and saltbushes may also be added to the list of promising forage plants.

The prevalence of blight renders potato raising a precarious venture. Experiments have been carried on at the station for two years in an attempt to develop a system of spraying which would control this disease. The results are still unsatisfactory but give promise that the disease may be overcome. Both Bordeaux mixture and lime-sulphur preparations have been used. The life of the vines is somewhat prolonged but not sufficiently to enable the potatoes to mature perfectly. There is need of a careful study of this disease by a trained pathologist.

Buckwheat and flax have given excellent results in growth and appearance of the plants and in yield. Little trouble seems to be experienced in the growth of these plants in Hawaii either from insect pests or diseases or even from soil conditions.

ENTOMOLOGICAL INVESTIGATIONS.

On account of the absence of the entomologist from the station on furlough for a considerable portion of the year the only systematic work in entomology carried on during the year was on tobacco insects and vegetable diseases. Many of these pests had been previously studied in Hawaii or elsewhere, but the life history of each pest was gone over again in detail so far as possible. Recommendations based on practical experience were made concerning the possible means of controlling these pests.

MISCELLANEOUS.

The interest aroused by the work of the station on kukui oil obtained from seeds of *Aleurites triloba* is shown by the requests which have come from the mainland and from various European countries for kukui nuts and oil for commercial use. There seems to be an active demand for this oil. About thirty-five paint and varnish firms have stated that they would like to buy this oil, some of them to the extent of 25,000 barrels a year. There has been considerable local interest in the kukui industry. Preliminary surveys have been made to determine the amount of nuts available, and one small plant was erected for expressing the oil. It was found in this plant that 40 gallons of oil could be obtained from a ton of nuts. This amount agrees closely with the results obtained in the laboratory at the station. A company is now being organized to express the oil. One New York firm is looking into the business with the idea of securing all of the available kukui nuts in the Territory for oil production. On account of the high value of the press cake as a fertilizer, it would seem best for the Territory that the oil be expressed in Honolulu. The press cake would thus be maintained as fertilizer, and a considerable amount saved on shipments made to New York.

The use of algaroba meal, the ground pods of *Prosopis juliflora*, is rapidly spreading throughout the Territory. The business now amounts to about $350,000 a year. The supply of algaroba beans, while larger than was at first anticipated, is not sufficient for local demands. There is no necessity, therefore, for seeking an outside market for this material. Some of the ranchers and dairymen are preparing to put up plants of their own. For this purpose a drier recently devised by G. F. Winter, of Lihue, Kauai, will be used. An ordinary alfalfa meal mill will grind the algaroba beans very satisfactorily after they have been dried. The Army in Hawaii uses algaroba meal as one-quarter of the grain ration for horses and mules. The interest in this feed is generally more active than has heretofore been the case. As a result of this increased interest there is little of the product which is allowed to go to waste. On some of the large estates the right to pick algaroba beans for a period of ten to fifteen years has been secured.

The experiments carried on by this station and elsewhere with arsenite of soda as a chemical spray for the destruction of weeds has brought about the general use of arsenite of soda for destroying weeds on rubber plantations and on many of the ranches. During the past year this spray was tested on many of the sugar plantations with excellent results and with a great saving in the cost of weed destruction. Several other plantations are now preparing to use the remedy extensively. On one large sugar plantation it has

been estimated from this year's work that the saving in cost of weeding alone has been about $100,000. In some of this work the formula used by the station has been modified to the extent of using caustic soda in the place of carbonate of soda to combine with the arsenic. The station is carrying on experiments to determine the fate of arsenite of soda in the soil and its possible effect upon nitrification and upon the physical properties of the soil. In pot experiments when arsenite of soda was added to the extent of 0.25 per cent of the soil, it was found to cause a pronounced deflocculation. The amounts used for spraying purposes thus far have showed no effect upon the soil.

In addition to breeding work with papayas the station has investigated the matter of producing papain. It was found that dried papain can be produced at a profit for about $2.50 a pound. Requests have recently been received for 2,000 pounds of the material at that price. A papaya grower on Maui is preparing to produce the material. In experiments at the station it was found that if in the early morning a dozen shallow lengthwise incisions, one-half to three-quarters inch apart, are made in a papaya fruit of good size, enough juice will be obtained to make half an ounce of dry papain. Fruits may be tapped on alternate days five to seven times in all. As soon as the fruit begins to turn yellow the milky juice flows less freely. The tapping wounds heal quickly and the fruit is not injured by tapping; in fact, the flavor appears to be somewhat improved, since a slight bitterness which characterizes the juice is thereby removed. It has been found that the papain is injured if the juice is allowed to come in contact with any metallic substances. The only precautions to be observed are that tapping be done with a glass, bone, or ivory instrument, and that the juice be collected in china or earthenware containers, and promptly dried. From the work along this line at the station it is estimated that papain to the value of $2 can be taken from each tree annually.

The use of dynamite for agricultural purposes, particularly in improving soil conditions continues to increase. The results obtained from dynamiting pineapple plantations at the end of the first picking season are satisfactory. The extended commercial experience indicates that dynamite, to be most effective, should be used when the soil is not too moist. If a charge of dynamite is exploded in a wet subsoil it has a tendency to form a more or less spherical cavity in the soil, packing the soil about the walls of the cavity without shattering the surrounding soil sufficiently. The use of dynamite in lawns is increasing. Many lawns which have stood for years without renovation show poor growth of grass on account of the extreme packing of the soil. Dynamite can be safely used in lawns for loosening the subsoil below and improving drainage.

The station has advocated since its establishment thirteen years ago the general use of legumes for green manuring in all branches of agriculture in Hawaii. Experiments have been carried on continuously with different legumes to learn what species were best adapted to practical use in the Territory. Among the generally cultivated legumes jack beans and lupines have proved most satisfactory. The German lupine has given excellent results at the station and elsewhere. Jack bean has the advantage of being a rapid and vigorous grower, and also of being relatively immune to plant lice and other insects which may check the growth of cowpeas. If the cowpeas were not so highly susceptible to the attack of aphids, it would be the legume to be recommended for green manuring. Under local conditions, however, jack beans or lupines or Mauritius bean must be considered most promising. For several years this station has been experimenting with an introduced leguminous weed known as rattlepod (*Crotalaria saltiana*). This legume is unusually hardy. It thrives in wet or dry districts. It will make a fairly good crop under rainfall of 20 inches and thrives abundantly under a rainfall of 200 inches. The seed will germinate promptly with little attention after scattering broadcast upon the soil. The plant is not useful for feed, but is an excellent green manuring crop. No insects do any harm to the plant except the blue butterfly, which merely reduces the number of pods. The seed of this plant can be readily obtained by offering children 10 cents a pound for it. Some of the independent cane planters, as well as the larger plantations, already have standing offers of 5 to 10 cents a pound for Crotalaria seed to be collected from the roadsides and elsewhere by women and children. The seed can not be obtained through seed dealers, but the supply to be obtained from waste places seems to be adequate for present purposes. The Crotalaria has the advantage over cultivated legumes that the seed may be sown without any previous preparation of the soil and of course without cultivation after seeding. In old cane fields, after the last ratoon crop is removed, the trash may be allowed to remain, as well as all weeds which naturally spring up. In order to increase the amount of plant material in the soil Crotalaria seeds may be scattered among the trash and weeds and even under these conditions the plant will make a satisfactory growth. The demand for jack-bean seed is increasing rapidly. The price offered is 5 cents a pound in ton lots. The supply is quite inadequate, but a number of homesteaders are preparing to grow the seed for neighboring plantations.

As already indicated, legumes are coming into use on sugar plantations to supplement the amount of humus derived from trash. The tendency at present is to abandon the burning of cane trash and to allow all this material to rot on the soil or to plow it under. The

results obtained from this economic use of humus material are so apparent that the practice of burning will probably be abandoned altogether within a few years. On several plantations fields which had become the poorest on the whole plantation gave the largest yield during the past year as a result of plowing under humus-forming material, but without applying excessive amounts of commercial fertilizers.

Analyses were made of samples of coffee from coffee cherries uninfested with fruit fly, badly infested with fruit fly, and also from half-ripe cherries taken four or five days before they would be completely ripe. No chemical differences in the composition of the coffee were noted in these different samples. Coffee was prepared for drinking, however, from all the different samples by three different methods, and the coffee was submitted to several persons for their opinion as to the flavor and other qualities of the different samples. All persons to whom the samples were submitted agreed that the sample from infested fruit was slightly insipid and poor in quality, while that from the fruit not quite ripe was pronounced best in flavor. The only explanation which can be suggested at present for this is the fact that the half-ripe fruit comes to the mill in an uninjured condition, while the cherries from ripe and partly infested fruit are nearly all ruptured and in process of fermentation. The fermentation of the whole cherry rapidly develops a putrefactive odor which apparently affects the flavor of the berry injuriously. As a result of these findings coffee growers are picking their fruit a little greener than heretofore, and are thus securing coffee of better flavor and avoiding the excessive infestation of the fruit fly.

A further test was made to determine whether infestation with the fruit fly might cause a loss of weight in coffee. Using the same number of coffee berries from infested and uninfested fruit it was found that the weight of berries from infested fruit immediately after pulping was 5 per cent less than that of berries from uninfested fruit. The first weight was taken after pulping and allowing the parchment to become dry on the outside. Weighings were made from time to time after removing the parchment and silver skin. It was soon observed that the weights of the two lots of berries began to approach each other. When the coffee came to a constant weight and was considered dry the weights of the two lots were the same. It would appear, therefore, that little or no loss of weight in the coffee berry is caused by infestation of the fruit fly.

An unusual amount of damage from rats on the island of Molokai led to a test by the station of the value of a rat virus in destroying this pest. The virus was distributed about a year ago. Dead rats were found within a week or two near all the points at which the virus was

distributed and have been found whenever search was made up to the present time. Apparently the infection has persisted for a whole year with the result that the number of rats has been reduced about one-half. No evidence has appeared that this disease which persists among rats can infest other animals.

Experiments are now in progress to determine the applicability of cold storage to various tropical fruits. It has already been found that holding fruit infested with the fruit fly for a period of ten days at a temperature of 32° F. destroys the fruit fly in whatever stage it may be present. Perhaps cold storage will be accepted as a sufficient means of rendering fruit such as avocados safe for importation into the United States. It has been demonstrated that avocados may be held without injury to the fruit at a temperature of 32° F. for at least two months. The same has been found to be true for star apples and water lemons. Figs have been held for one month at 32° F. with beneficial results to texture and flavor of the fruit. Pineapples came out of a month of cold storage at 32° F. with excellent flavor. The only fruits which have thus far shown a tendency to absorb a disagreeable cold-storage flavor are papayas and mangoes.

Frequent attempts to produce alfalfa hay in Hawaii have yielded rather unsatisfactory results. It seems impossible to secure a good quality of hay. Usually, alfalfa can not be dried in the open air in Hawaii so that it will not heat and mildew when stored. Plans are now being made to dry alfalfa by the devices which are already used for drying algaroba beans. A test of one of these machines on a small scale produced an excellent quality of alfalfa hay which was later ground into meal. The meal was greener and less bleached than the ordinary alfalfa meal imported from the mainland.

A disease of bananas has been observed in Hawaii for many years and has sometimes been mistaken for the Panama disease. It, however, obviously differs from the Panama disease. Infested leaves show spores of a Fusarium, and at the border line between healthy and diseased tissue a bacterial organism was found by Dr. H. L. Lyon in nearly pure cultures. The most obvious symptom of this disease is the death and decay of the terminal young leaves or at least a yellowing and wrinkling of these leaves. Infected plants do not produce the ordinary large leaves, but narrow, yellow, wrinkled ones. Small distorted bunches of fruit may also be formed. These bunches do not fill out properly. It has been found that where the disease is neglected it may gradually become more serious and infect a large percentage of the plants on a given plantation. Spraying with fungicides appears not to be effective, since the fungus is already within the tissues of the plant before the disease can be detected by its symptoms. If, however, diseased plants are cut out and destroyed by fire as soon

as they are noticed the disease can be cheaply and effectively held under control. The disease in question seems to affect chiefly the Chinese banana.

During the past year the hen flea (*Sarcopsylla gallinacea*) appeared in Honolulu and has been spreading rapidly. It is found on chickens, rats, cats, and perhaps other animals, and a bad infestation may kill the young chickens. The fleas are similar to the dog flea and have the habit of burying their heads in the skin of young chickens about the eyes and neck and under the wings, where they remain attached like ticks. A number of remedies were tested in attempts to destroy this pest of young chickens. The remedies included carbolated vaselin, containing 2 per cent of carbolic acid; kerosene; zenoleum in a 3 per cent solution, and carbolic acid in 1, 2, and 3 per cent solutions in glycerin and water. The remedies were applied to the heads of young chickens by means of a small brush. The hen flea is evidently very resistant to contact insecticides. About 75 per cent of the fleas were killed with a single application of kerosene. All of the fleas were killed by an application of carbolated vaselin and a 3 per cent solution of carbolic acid. Zenoleum in a 3 per cent solution was about as effective as kerosene. The pest is found in the soil about infested yards and in cracks of buildings. The trouble is so serious that poultry raisers should thoroughly spray infested yards. Since rats may also carry these fleas, this constitutes one more good reason for a warfare on rats.

During the year the following publications were issued by the station:

Annual Report for 1913.
Bulletin 29, Ornamental Hibiscus in Hawaii.
Bulletin 30, The Effect of Heat on Hawaiian Soils.
Bulletin 31, Rice Soils of Hawaii.
Bulletin 32, The Papaya in Hawaii.
Bulletin 33, The Organic Nitrogen of Hawaiian Soils.
Bulletin 34, Tobacco Insects in Hawaii.
Press Bulletin 45, An Experiment in Marketing under Territorial Auspices.
Press Bulletin 46, Poultry Management.

REPORT OF THE CHEMICAL DEPARTMENT.

By W. P. Kelley.

The work of the chemical department has been continued along the lines mentioned in the last report. The great importance of soils and the many practical difficulties and great expense now incurred in their management and fertilization are sufficient reasons for devoting much study to this subject. The efforts of this department, as in previous years, have, therefore, been devoted mainly to soil investigations. In view of the limited state of knowledge concerning soils and the fundamental importance of the subject, it has been deemed wise to devote considerable time to the investigation of problems of a scientific rather than of a practical nature. In this work effort is being made to find the reason for some of the soil processes that are now only imperfectly understood and to render the common soil practices more intelligible. In this connection studies were undertaken on the bacterial processes of soils, on the physical effects of fertilizers and other chemical substances, and on the availability of phosphates. In addition, a study on the composition of tropical fruits in the islands has been completed, and at present an investigation of the organic phosphorus of rice is being made. A limited amount of time has been devoted to miscellaneous analyses.

BACTERIOLOGICAL INVESTIGATIONS.

The availability of nitrogen in soils is of great importance. There are many forms of nitrogen in soils which previous investigations have shown to be available to plants. Most of these arise from vegetable proteins by the action of bacteria, and are susceptible of further decomposition. Usually investigations on this subject have dealt with ammonification, nitrification, denitrification, and nitrogen fixation, without giving much consideration to the intermediate changes between the complex proteins and the end products. However, since different organic nitrogenous fertilizers become decomposed and converted into ammonia and nitrate at different rates, and in view of the fact that different proteins yield different amounts of hydrolytic products which are of unequal availability and which probably undergo further decomposition at different rates, it is a matter of interest to follow the course of the changes taking place.

The initial decomposition may be assumed to be of a hydrolytic nature and probably to result from the action of bacterial enzyms, but whether *deamidization* is a hydrolytic or oxidative process remains to be determined. From previous work on the organic nitrogen of Hawaiian soils it was suggested that bacteria cause a more rapid decomposition of the diamino acids than of the other groups present in proteins. Extending these investigations to include a study of the bacterial decomposition of nitrogenous fertilizers, it has been found that the basic nitrogen compounds (diamino acids) actually disappear more rapidly than the other groups. The work is being continued with the use of pure proteins.

Closely related to the hydrolytic decomposition of proteins in soils is the ammonification of the hydrolytic products. Investigations will be undertaken on the ammonification of the more common amino acids and acid amids of protein cleavage. In this work special study will be given to the amino acids as sources of energy to bacteria as well as to determine the ammonia formed.

PHYSICAL STUDIES.

Evidence has been accumulated in recent years on the importance of physical factors in soils. From the work in this laboratory and the experience of farmers it is certain that physical factors play a very large part in Hawaiian soils. Soil films and colloids especially appear to play an unusually prominent rôle in their fertility. The striking effects of heat on the growth of plants, the high power for absorbing fertilizers, the importance of aeration, the abnormal effects of lime, and the influence of volatile antiseptics, all seem to be related to colloids. The data already obtained in studies on these subjects emphasize the need for much further study along these lines.

As bearing on these subjects, an extensive series of experiments has been carried out on the moisture relations in soils as affected by fertilizers. Such phenomena as capillarity, percolation, flocculation, cohesion, specific gravity, vapor pressure, and hygroscopic moisture have been studied and an unusually large array of data obtained. A number of different soil types were used and very striking results obtained. It has been conclusively demonstrated that fertilizers do exert measurable physical effects and that there are physical pecularities in Hawaiian soils not hitherto met with. In general, it may be said that no two of the different soils studied were affected to the same degree, and frequently not even in the same order, by a given fertilizer.

The results obtained still leave the subject in an uncertain state. The data must be considered to be empirical, and the conclusion drawn as tentative only. Nevertheless, progress has been made.

The subject is one of unusual complexity and will require the patient efforts of years for its elucidation. However, the conclusion seems to be justified that film pressure and colloids are very important phases of Hawaiian soils, and are affected by fertilizers in some instances to a striking degree. The results of this investigation are being prepared for publication by Mr. McGeorge, assistant chemist.

THE AVAILABILITY OF PHOSPHATES.

Experiments have been in progress for more than a year on the availability of phosphates. This work was undertaken in cooperation with the basic slag committee of the Association of Official Agricultural Chemists, but in view of the practical interest in the subject, the work is being extended to include a wide range of phosphates, using a number of soil types and crops. Hawaiian soils contain abnormal amounts of iron and alumina and are able to absorb unusual quantities of soluble phosphates. Consequently, the availability of phosphates is a question of special interest.

The results to date show that different crops vary greatly in regard to the effects produced by different phosphates. Immediately following the application, different soluble phosphates seemed to affect the growth of millet similarly, while insoluble forms were ineffective. After remaining in the soil some months in conjunction with decaying organic matter, however, rock phosphate became as effective as soluble phosphates, and both forms then gave marked increases in growth. In this work such questions as the reversion of soluble phosphates by lime, the lasting effects of phosphates, the absorption of phosphate by the plant, and the effects of decaying organic matter on availability are being studied.

THE COMPOSITION OF HAWAIIAN FRUITS.

The composition of tropical fruits is a subject of much interest. A number of analyses of such fruit have previously been made, but frequently of fruits that had been shipped over long distances after having been picked. With few exceptions, there are no records of the composition of Hawaiian fruits. Therefore, it was deemed wise to analyze the fruits growing in the islands. In this work the different fruits were allowed to ripen thoroughly on the tree, and were analyzed immediately after picking. The results obtained are therefore of special interest as showing the composition of a large number of normally ripened fruits. A study of the changes taking place during the ripening of bananas and papayas was also made. The results are given elsewhere (see p. 73).

THE ORGANIC PHOSPHORUS OF RICE.

The mineral constituents of foods and feeds are coming to be more seriously considered in nutrition. Among these constituents phosphorus is of especial interest. This element has long been known to occur in plants in both organic and inorganic combinations, but the specific phosphorus compound occurring is a matter of uncertainty. Aside from lecithin and inorganic phosphates, very little until recently was definitely known. From the work carried out at the New York State station and elsewhere, it appears that wheat, oats, corn, and cottonseed meal contain rather large amounts of phytin. In view of the great importance of rice as a food, a study of the forms of phosphorus contained in it is of special interest. This work was undertaken near the close of the year, but interesting results have already been obtained.

REPORT OF THE ACTING HORTICULTURIST.

By C. J. Hunn.

J. E. Higgins, the horticulturist of the station, was away during the past year on leave of absence. V. S. Holt and the writer carried on the work as outlined at the beginning of the last year, and attempted but few new lines.

PAPAYA INVESTIGATIONS.

This station has received during the past two years seeds of many varieties of papaya, *Carica papaya*. These seeds have been planted and many of the seedlings are growing at the station. Others have been distributed among private individuals. In the latter case, the station reserves the right to select the best trees and to propagate from these superior varieties. Many of these trees are now coming into bearing.

Mr. Holt has presented elsewhere [1] a more complete report of the types of papaya flowers and fruits found in the F_2 generation of No. 3198, which were grown from two hermaphrodite flowers fertilized with their own pollen. At the time the report was written only 343 trees were old enough to exhibit sex and fruiting characteristics. There are now 454 trees which show the following types:

Types of papayas grown from close fertilized fruits.

Form No.	Character of fruit.	Number of trees.
1	Pistillate	164
1 and 7	Pistillate and pentandria	1
1, 4, and 9	Pistillate, elongata, and intermediate	2
1, 4, and 7	Pistillate, elongata, and pentandria	2
4	Elongata	108
4 and 9	Elongata and intermediate	2
7	Pentandria	1
8	Pentandria and elongata	148
7, 4, and 9	Pentandria, elongata, and intermediate	5
9	Intermediate	0
2	Staminate	16
3	Correæ	5
	Total number of trees	454

The main object in the breeding and selection of this type of papaya is the elimination of the staminate plants. These 454 trees may be grouped as follows:

	Per cent.
Fruit bearing, exclusive of correæ	95.37
Correæ	1.1
Staminate (sterile)	3.52

[1] Hawaii Sta. Bul. 32, pp. 34, 35.

Since with the diœcious type of papaya, one theoretically expects 50 per cent fruit bearing, the attainment of over 95⅓ per cent fruit bearing, exclusive of correæ, is a great step in the elimination of the staminate type.

Contrary to expectations, the elongata type has increased in percentage, which gives promise of the ultimate development of a pure strain of uniformly cylindrical fruits. Since this type exhibits general uniformity and is of excellent quality, the work in the future will deal strictly with the elongata type and with the elimination of all the other types of flowers and fruit.

CHANGE OF SEX IN THE PAPAYA.

As noted in a previous publication,[1] the forms of the papaya tend to be variable. The staminate flower of the male trees possesses an undeveloped or abortive pistil. Several authenticated cases of the complete change of a male tree to one purely female have been presented in scientific publications. Previous to this time the station has been unable to present favorable evidence on this point from experiments actually performed in the station's orchards. Early last summer Mr. Holt removed the tops of 22 sterile staminate trees. These trees all made considerable growth and now show the following characteristics: Sterile staminate, 18; correæ, 2; pistillate, 1; and elongata, 1.

The large percentage of sterile staminate trees may be due to the fact that the larger number were of the type of papaya which, under normal conditions, produces equal numbers of staminate and of fruit-bearing trees.

The two staminate trees that changed to correæ appeared in variety No. 2978, in which there are 56.25 per cent pistillate, 12.50 per cent correæ, and 31.25 per cent sterile staminate. The two trees that made the complete change in sex from sterile staminate to one pistillate (see Pl. I, fig. 1) and one elongata, appeared in the F_2 generation of No. 2355:1, in which there are 95.37 per cent fruit bearing and only 3.5 per cent sterile staminate. The two trees that changed sex were the only trees of this type that had been beheaded. As has been noted,[1] there are several possible hypotheses which may account for this change. At present, the only possible explanation of these changes in sex is that there is a preponderant tendency to fruit bearing in No. 3198 and a like tendency to the correæ form in No. 2978.

[1] Hawaii Sta. Bul. 32, pp. 25–27.

MANGOES AND AVOCADOS.

The mango and avocado orchards have been gradually coming into bearing during the past several years. Figures on the bearing age of the various types of trees are as follows:

Bearing age of mango and avocado trees.

	Number of trees.	Average age at time of bearing.		Number of trees.	Average age at time of bearing.
Mangoes:			Avocados:		
Seedlings	48	6 yrs. 3 mo.	Seedlings	27	7 yrs.
Budded	15	3 yrs. 8 mo.	Budded	11	2 yrs. 11 mo.
Inarched	11	2 yrs. 10 mo.			

BAGGING OF FRUIT.

Since the advent into these islands of the Mediterranean fruit fly (*Ceratitis capitata*) many kinds of fruit, on approaching maturity, have been covered with heavy paper bags (Pl. I, fig. 2). The larvæ of *Amorbia emigratella* and of *Cryptoblabes aliena* cause considerable trouble by weaving their webs among the terminal leaves and the flowering panicles of the mango. In order to secure the best fruit it is necessary to remove such webs, as well as diseased and misshapen fruit. While performing these operations but little additional effort is required to place and tie a bag over each fruit cluster. The individual fruits ripen more uniformly but lack the color of those exposed to the sun. Several varieties of the Indian mango have been found to be practically immune to the attacks of the fruit fly.

HIBISCUS.

This station participated in the hibiscus show held during the Mid-Pacific Carnival Week in February, at which time the station's exhibit of varieties, which consisted of Mr. Holt's personal collection of imported and original varieties and those which he has since originated, was unanimously granted the first award. This recognition of the station's collection has created a demand which has been filled in part by the distribution of over 30,000 cuttings and seedlings during the past three months. Mr. Holt has selected the best varieties of hibiscus, and some 200 grafted plants are now being grown in soy tubs for exhibition purposes.

Mr. Holt has outlined a number of experiments in the breeding of hibiscus, one of which is worthy of mention. Yellow hibiscus are exceedingly rare. The process of crossing adopted by Mr. Holt has given a clue as to how this color may be developed. A single orange hibiscus with upright stigmas (39:1) was introduced several years ago from Germany. The F_1 generation (145:1) was self-fertilized

and produced a flower much like its parent. This F_1 hybrid was crossed with 1E (533:1),[1] a single pale cerise flower with white veins and throat and a pale yellow column. The resulting cross, F_2 (102:2), has pale crimson petals with light veins, a dark crimson eye and upright stigmas. The F_2 cross was self-fertilized to produce F_3 (395:1) V. S. H. Parents 1E×Single orange (upright).

The new variety may be described as follows:

Moderate growth, freely branching, brownish bark, green twigs, good foliage.

Leaves ovate, acuminate, serrate, nearly smooth, dark green, 1½–2 inches wide, 2¾–3½ inches long, petiole ¾–1 inch long.

Flower 5 inches wide, scarlet orange with yellow veins, crimson eye, column yellow, crimson at the base, stigmas crimson, appressed, peduncle 2 inches long, bracts 6, green, not spreading, self-seeder.

This hybrid, No. 395:1, has been self-fertilized and also used as the male or as the female parent in a large number of crosses, the seedlings of which will be grafted on thrifty stocks to hasten their flowering.

NEW PLANTS.

A number of years ago the station collected in Honolulu several slabs of an almost spineless cactus. Dr. W. T. Brigham states that he has known this cactus for a long time and that he believes it was introduced by Don Marin. Dr. Brigham suggests that this cactus be called "The Manini Cactus" (the Hawaiian form of Marin). These cactus slabs were grown into plants, which after subsequent subdivision have developed into a hedge nearly 100 feet long. A description of the plant is given herewith:

OPUNTIA.—Plant averaging 6 to 8 feet in height, shrubby and much branched; basal slabs forming the trunk, averaging 10–14 inches long, 5–6 inches wide, 1¾–2¼ inches thick, joints 2–2½ inches in diameter, smooth and deep green in color, becoming rough and grayish at the joints; mature slabs 10–14 inches long, 4–5 inches wide, ⅜–1 inch thick, narrowing slightly toward the center of the slab, obovate in form, olive green, and inclined to be slightly woody; immature slabs 8–10 inches long, 3–3½ inches wide, ¼–⅜ inch thick, obovate, pea green, and very fleshy; spines absent or at times small and inconspicuous; after being developed into short fleshy leaves, sometimes with spiny terminals, these appendages fall as the slabs mature; when present these spines are two in number, $\frac{3}{32}$ inch long, light gray below, brownish at the tips; spinules absent or very small and basal, 2 to 3, grayish; spinules are numerous and very small in areoles on the fruit; flowers are borne singly at the tips of young branches and consist of a modified joint, bearing at the apex the floral portions, the ovary being buried in a slight depression in the joint; basal joint 1½ inches long, ⅞–1 inch wide, pear-shaped to globose, green, areoles bearing numerous small spicules, floral portion 1½ inches long, 1¼ inches wide, never spreading; petals averaging 25, outer ones short and fleshy, inner ones long and thin, rose to pink in color; stamens and filaments averaging about 300, filaments 1¾–2 inches long, yellowish at the base, carmine above; stigma and style green, stigma 7 parted; style 2 inches long; ovules numerous and contained in the fleshy fruit; the joint changes to a succulent and juicy fruit,

[1] Hawaii Sta. Bul. 29, p. 42.

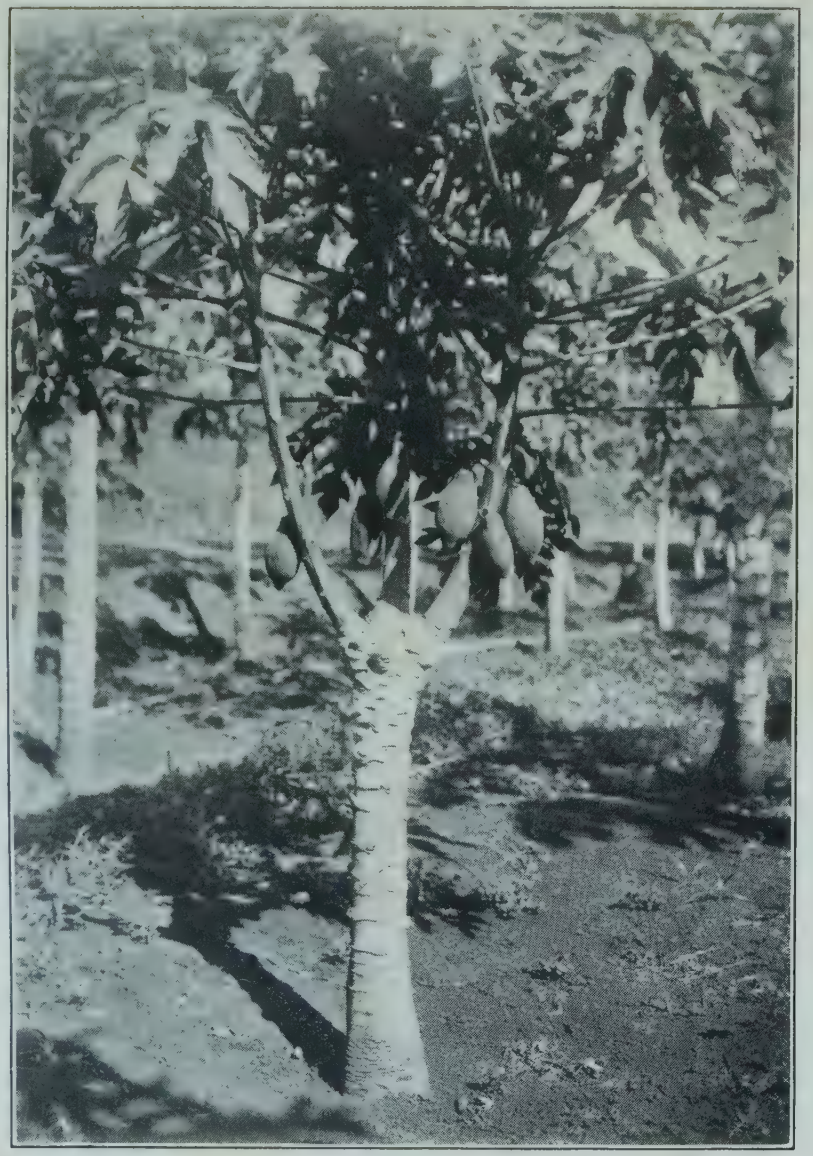

FIG. 1.—STERILE STAMINATE PAPAYA TREE CHANGED TO PISTILLATE BY BEHEADING.

FIG. 2.—MANGO, SHOWING FRUITS COVERED WITH PAPER BAGS.

FIG. 1.—OPUNTIA, AN ALMOST SPINELESS CACTUS.

FIG. 2.—CLAUSENA LANSIUM, WAMPI.

1½–2 inches long, 1–1½ inches wide, pear-shaped to globose, areoles with numerous small spicules, claret red; pulp deep claret red, many seeds, watery and almost tasteless.

Rapid growth, very productive, and best propagated from slab cuttings, since seed are liable to be cross-fertilized with the spiny Opuntias.

Since this cactus is of rapid growth and comparatively free of spines, it is worthy of attention as an ornamental hedge and as a fodder plant. (Pl. II, fig. 1.)

One of the little-known fruit plants introduced from China is the wampee, whose edible berries are highly esteemed by the Chinese and others. There are about a dozen trees in bearing in Honolulu.

Clausena lansium; C. wampa or *Cookia punctata*. Wampee or wampi. Aurantiaceæ. (Pl. II, fig. 2).—A small tree, 18–20 feet, with luxuriant foliage, native of South China; nearly glabrous pinnate leaves; small dense panicles of whitish sweet-scented flowers, produced in April; fruit ripens in June and July; an edible berry, borne in clusters like the grape, individual fruit nearly globose, the size of a large marble, rough, tough, orangelike rind pale straw yellow in color and covered with glands full of green balsamic oil; seeds 1 to 3 nearly filling the fruit cavity; a small quantity of almost colorless juicy pulp between the seeds and the rind, with an agreeable, aromatic acid taste.

Propagated by seeds and layers. Often used as a dessert fruit, but mostly for preserves. The leaves are used in flavoring. This fruit is subject to the attacks of the fruit fly and should be covered with paper bags.

THE PINEAPPLE SEEDLINGS.

The pineapple seedlings Nos. 3059 and 3060,[1] were transplanted last October from quart tins into 12-inch flower pots. Since the pineapple plant is greatly influenced by the physical character of the soil, considerable black sand was incorporated into the soil mixture. There were 48 plants in lot No. 3059, of which 31 plants are now growing. These plants vary from 1 to 8 inches in height and from 1½ to 14 inches in the spread of the foliage. In character they may be listed as excellent 1, fine 5, good 8, fair 8, poor 8, and very poor 1; no spines 4, very few spines 11, few spines 5, and very spiny 11. There were 53 plants in lot No. 3060 of which 41 plants are growing. These plants vary from 1½ to 12 inches in height and from 2 to 23 inches in the spread of the foliage. In character these plants may be listed as excellent 6, fine 8, good 9, fair 10, poor 5, and very poor 3; no spines 8, very few spines 13, few spines 1, and very spiny 19. In color the leaves of these seedlings vary from green to red and bronze, either as a solid color or in stripes. A number of these seedlings give promise of developing into superior plants and will later be planted under field conditions in order that the character of fruit may be ascertained.

[1] Hawaii Sta. Rpt. 1913, p. 23.

THE PROPAGATION HOUSE.

The solar heater which was originally installed in the propagation house when the latter was reconstructed proved satisfactory only during the afternoons of sunny days. A small gas heater and a water boiler were placed in the propagation house. The hot water did not circulate as rapidly as desired and the benefits were not commensurate with the amount of gas consumed. The plan of having the hot-water pipes in direct contact with the sand also proved unsatisfactory because the sand acted as a nonconductor of heat. The water pipes have been placed in an inclosed chamber just below the sand bed. A concrete pit has been constructed at one side of the propagation house, inside of which has been installed a large gas heater, thermostat, and a boiler. Other appliances, such as water, gas, and safety valves and an auxiliary water container, have been placed in position. Preliminary experiments have proved that this arrangement is efficient, but further work is necessary before definite conclusions may be drawn.

FIELD WORK.

The usual field work of this department has occupied considerable time. The various orchards have been pruned, fumigated, and given general cultural attention. Cover crops were sown at the proper season and were later turned under to maintain the fertility of the land.

ACCESSIONS.

Among the accessions of the past year which are worthy of note are several species and a number of varieties of papaya; budwood of selected local and California varieties of avocado; budwood of the Carabao and Pahutan mangoes; a variety of cucumber with a thick, almost reticulated rind, which is said to be somewhat resistant to insect pests; a species of pipe gourd; a collection of 12 varieties of spineless cactus; several new varieties of sweet potatoes; two new varieties of roselle; and plants of *Lansium domesticum* and three varieties of Garcinia.

This station receives frequent requests for assistance in the selection of agricultural materials. In order to be prepared for such demands, there has been gathered together an excellent collection of American and foreign seed and plant catalogues, spraying machinery and spraying-materials catalogues, farm-machinery catalogues, and catalogues of horticultural tools and requisites.

DEMONSTRATION AND DISTRIBUTION.

There has been an unusual demand for advice and assistance from those interested in homesteads. While this department makes no pretense of keeping a stock of plants and seeds on hand for distribu-

tion, many of these requests have been filled. The principal plants distributed this past year have been seeds and plants of the papaya, the Kusaie lime, and the rough lemon. The quantity of budded citrus and budded and grafted avocados and mangoes has not been sufficient to supply the sale demands. This department has from time to time filled requests made by other scientific institutions.

NEEDS.

The horticultural department is in need of a rat-proof room for the hardening off of new potted seedling plants, a more effective and permanent soil sterilizer, and a large storage space for tin cans and seed flats.

In closing it is desired to express appreciation of the faithful and efficient services of Valentine S. Holt, acting assistant horticulturist, James H. Cowan, assistant, and of those who have done the detail work of the propagating house and orchards.

REPORT OF THE AGRONOMY DEPARTMENT.

By C. K. McClelland and C. A. Sahr.

Work in this department for the year has been carried on along much the same lines as in previous reports. Taken altogether, the results obtained have not been entirely satisfactory on account of weather conditions and pests. The most complete failure was with corn. Corn was planted in November following several good rains, and grew well from the start. Severe winds during January whipped the plants so badly when they were in tassel that no grain was produced. In a plat in which germination was tardy and the plants less advanced, a better result was obtained.

RICE.

The work with rice is being continued on a small scale in Nuuanu Valley. The lines of work include trials of varieties, aeration of the soil previous to planting, rotation, green manuring, and fertilization. Fertilizers have given no definite results on this land for the past two crops, probably due to the richness of the soil. These plats had not been planted for several years, and a considerable amount of grass and roots was turned under in preparing the land for cultivation. The two following varieties have been grown for the first time during the past year:

Bezembo, a Japanese variety obtained from James Armstrong, of Pearl City, and which is grown quite extensively by him. It was brought from Japan by some of his laborers, and it is preferred by them to the Shinriki variety which Mr. Armstrong has also grown from paddy furnished by this station. In the fall of 1913 it yielded about the same per acre as did Shinriki, but slightly less than did Omachi. It blooms and matures in about 10 days less time than either of the other varieties named.

Long Nyah Yin is a Chinese variety obtained from the Oahu Rice Mill Co. It is a short kernel variety and considerably later than the Japanese varieties. However, the Chinese claim that it will produce two crops. It is also said to be as well or better adapted to salt marsh lands as the No. 19 variety heretofore grown on such lands.

The importation of rice into Hawaii continued at about the same rate, the amount for the fiscal year ending June 30, 1912, being

30,000,000 pounds of rice in the brown; for the year ending June 30, 1913, the amount was 32,000,000 pounds. The shipments from Hawaii to the United States during the calendar year of 1912 were 471,793 pounds, and during 1913, 479,920 pounds. The shipments from the United States to Hawaii during the same years were 52,705 and 319,975 pounds, respectively. The shipments to the United States were mainly of Chinese and Hawaiian rice, while those to Hawaii from the mainland were mainly of Texas-grown Japanese rice. In addition to these shipments, the Quartermaster's Department of the United States Army brought in, during the year ended May 1, 1914, 183,000 pounds, previous to which date their supply was obtained locally. The increase of shipments from the United States in more recent times would seem to indicate that many of the Japanese population have concluded to eat more of the cheaper American rice and less of the imported dearer kinds.

SMALL GRAINS.

Wheat, oats, rye, and barley were planted on limited areas. The wheat rusted badly, and although a few heads matured, the results are such as to hold out little hope of successful wheat raising under local conditions. Rye did excellently at first, and more completely covered the soil, and at an earlier date than did any of the other small grains. While the stand was perfect, when the grain headed out, the appearance was that of a thinly planted plat—the number of heads being about 30 per cent of what they should have been. Oats did better than during the previous year, and averaged, when headed out, about 45 inches in height. As with rye and wheat, the number of heads formed was a very small percentage of what one would term a good crop. Oats at the station make rather a slow growth, and lodge badly before maturing. The wide-leaved varieties are particularly subject to rust.

Barley, though slow in its early growth, headed out better than either oats or rye. Both varieties grown headed at the same time, matured in 150 days, and made a growth of 34 inches. The success of this crop is still uncertain, and further trial is required.

The small grains are attacked by rice birds and sparrows, and with these pests in abundance it is impossible to obtain any accurate data upon seed production.

SORGHUMS.

In an experiment with a sweet sorghum, a nonsaccharine sorghum, and Japanese cane for yields of forage over a long period, the sweet sorghum has yielded, in four cuttings, 47.1 tons per acre, and the nonsaccharine variety 49.8 tons in three cuttings. The Japanese cane cut for the first time yielded 102 tons of forage per acre 453 days

after planting. The testing of several varieties of African sorghums for the Office of Forage Plant Investigations at Washington has been attended with some difficulties, such as flood, drought, and severe checking of soil, and the attack of birds. Because of unthriftiness, the first planted sorghums were cut back about September 1, and the ratoon crop allowed to produce seed in the late fall and winter. Because of birds no heads except those covered with wire cloth (held on with spring clothespins) matured, and for that reason very few and often imperfect heads were available for shipment to Washington. A duplicate planting was made on the Wyllie Street plats in October, but these did not reach normal size—heading out early because of cool weather.[1]

SUDAN AND OTHER GRASSES.

Sudan grass planted November 22, 1913, did excellently well. The first cutting, on March 9, 1914, yielded at the rate of 31 tons per acre of green forage; the second cutting, made May 8, was at the rate of 30 tons. The stems of Sudan grass run quite uniformly small and with wide leaves, although occasional plants show a coarseness of stem. The quality of the grass could probably be maintained and improved by roguing out these coarse stemmed plants as fast as they are found, to prevent cross-pollination and consequent deterioration of the seed. With Tunis grass, on the contrary, there is more variability. The majority of the plants have a stem slightly larger than that of Sudan grass, but the leaves are much narrower, and there are many variations with coarse stems and wider leaves. (Pl. III, fig. 2.) Sudan grass is much superior at lower, and Tunis at higher, elevations. At Schofield Barracks the Quartermaster's Department put in about four acres of the Sudan, this being the largest planting as yet made in the Territory. The agronomy department has distributed seed in small amounts to some 40 farmers on the several islands.

New pasture grasses that may prove to be of some value upon lower lands with light rainfall are: Teff grass (*Eragrostis abyssinica*), *Chrysopogon montanus*, and Giant Bermuda. The latter grass has larger stems and leaves and grows more rapidly than does the ordinary manienie. *Chrysopogon montanus* is a perennial grass which has a habit of growth very similar to pili (*Heteropogon contortus*) and it will probably be one of value in the pili country. It will

[1] These long season nonsaccharine varieties of sorghum rarely head out during the warm summer months but seed freely in the cooler fall, winter, and early spring months. No. 309 (S. P. I. No. 25330) when cut Sept. 16, yielded 31 tons per acre of green forage, had no bloom whatever. (See Pl. III, fig. 1.) It and the new varieties now being tested, have been cut twice during the cooler months, the new ratoons heading out again a short time after each cutting. It is possible that dryness during cool weather may influence the bloom somewhat, but it is certain that dryness in hot months exercises no influence. For best yields of seed, however, sorghums should not be cut back in late summer, as was done in the case above mentioned, since with the first rains of the fall, if standing, they grow rapidly and make full crops, but if cut they bloom early with not sufficient growth of plant to fill and mature the seeds.

require the same judicious management as does the pili grass. Teff grass is said to be an annual, but has ratooned freely here during its first trial. From a planting made November 15, 1913, the third cutting of mature grass and seed was made May 27, 1914. The stems are small, the leaves fine, and the entire plant appears to be quite palatable. It seeds freely and will doubtless be able to propagate itself under range conditions much as does kakonakona (*Panicum torridum*).

A number of other grasses were tried out in the grass garden during the year, and although many of them did well, further trial will be necessary in order to determine their value. Mitchell grass (*Astrebla triticoides*), Judd grass (*Leptochloa virgata*), *Paspalum stoloniferum*, molasses grass (*Melinis minutiflora*), *Paspalum virgatum*, *Phalaris bulbosa*, and Texas blue grass are worthy of mention. The American "Buffalo grass" (*Bulbilis dactyloides*) from Kansas seed started very slowly but is making much better growth as the summer months come on. This is one of the best grasses on the Great Plains area of the United States and should be very valuable on the lower dry lands here.

AUSTRALIAN SALTBUSHES.

Several species of Australian saltbushes (*Atriplex* spp.) lately imported into Hawaii are giving satisfactory results as pasture or cover crops for extremely dry and barren localities. Three varieties tested out are the round-leaved saltbush (*A. nummularia*), slender saltbush (*A. leptocarpa*), and gray saltbush (*A. halimoides*). The first-named species has exceptional qualities in its quick, sturdy growth and prolific seeding habits, while the gray and slender saltbushes, though maintaining vigorous growth, are inclined to seed only during the late summer and fall months. However, all have their merits as sturdy, long-period cover crops.

POTATOES.

But few successful potato crops have been harvested in recent years, due to attack from fungus diseases, of which a late blight seems to be the most serious. The stem and root rot, due to *Sclerotinia rolfsii*, which attacks the stem of the vine in its early growth, is generally overcome by deep and thorough cultivation. It has not been determined whether the blight attacking potatoes in Hawaii and the rotting of tubers are caused by the same organism, but on the mainland where potatoes have been killed by blight (*Phytophthora infestans*) resulting tubers were found to be involved in a soft or wet rot, particularly in instances of moist soil conditions. At the station the loss from rotting of tubers has been particularly large when left undug for several days after the killing of the tops by blight.

Difficulties in obtaining full stands have been corrected by entirely discarding the stem end of tubers for seed purposes. Seed treated with formalin by soaking in a solution of 1 pint 40 per cent formalin to 30 gallons of water produced tubers free from scab in every case except when the soil was freshly limed.

Some spraying experiments were conducted during the year. In each instance the spraying was begun when the plants were 6 or 8 inches high, and six to eight applications were given according to the life period of the vines. With White River potatoes no appreciable difference in yields of tubers resulted from rows sprayed with Bordeaux mixture [1] or copper sulphate and washing soda [2] over unsprayed rows, while with Burbank potatoes yields favored the use of Bordeaux mixture. With Irish Cobbler where an 8 : 8 : 60 [3] solution of lime-sulphur spray was applied in the last two applications the yields favored the lime-sulphur over Bordeaux mixture by an 8 per cent increase, the plants maintaining their thrifty appearance two days longer than those sprayed with Bordeaux mixture and twelve days over check rows. When the potatoes are attacked by the potato tuber moth (*Phthorimæa operculella*) or the flea beetle (*Epitrix parvula*) 1 pound of arsenate of lead added to 50 gallons of Bordeaux mixture is recommended.

BUCKWHEAT.

While buckwheat is best adapted to a cool, moist climate, excellent results were obtained from plantings made in early April. Though the blossoming period was attended by excessively hot, dry weather in May, no loss from the blasting of blooms was perceptible. The two varieties under test (Japanese and Silverhull) yielded 25 and 19½ bushels per acre, respectively, in 56 and 63 days. Buckwheat germinates readily and makes good crops in poor soil if well prepared. The ease and quickness of raising this crop recommends its use in regular rotation, particularly as a poultry feed. For best results buckwheat should be sown in drills one foot apart, requiring about one bushel of seed per acre.

FLAX.

Several trial plantings of flax produced good yields of flaxseed, but rather poor yields of straw. Flax requires a light soil well prepared before planting, germinates in 4 days under good conditions, and matures usually in 90 days. It can be drilled or broadcasted, care being taken to insure an even stand when fiber is wanted for manufacture. The average yield of two plantings upon the station grounds was 17 bushels of flaxseed per acre.

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[1] 6 pounds stone lime, 5 pounds copper sulphate, 50 gallons water.
[2] 5 pounds washing soda, 5 pounds copper sulphate, 50 gallons water.
[3] 8 pounds stone lime, 8 pounds sulphur, 60 gallons water.

FIG. 1.—AFRICAN SORGHUM, S. P. I. 25330.

FIG. 2.—SUDAN GRASS ON LEFT, TUNIS GRASS ON RIGHT.

RAPE.

Rape was planted April 5, and grew well at the start. By May 1, when it had gained a height of 10 inches, aphids appeared, and exceedingly hot and dry weather following caused the loss of the entire crop. There seems to be but little doubt that rape will make a good crop when planted at the right season, since it is known that cowpeas, which generally make successful crops, have been killed outright when checked by unseasonable weather conditions together with aphis attack.

LEGUMES.

Of the several legumes introduced during the year German lupine (*Lupinus hartwegii*) gained favor as a green manure crop, yielding at the end of 84 and 96 days, respectively, 9.8 and 18.6 tons green manure and 16.5 bushels of seed per acre. Its habit of growth, while low and spreading at the start, becomes erect and branching as the flower heads appear. Trials with Egyptian clover or berseem (*Trifolium alexandrinum*), Florida beggar weed (*Desmodium tortuosum*), and field burnet (*Sanguisorba minor*) gave fair results, but the field burnet in every trial failed to set blooms and seed. The beggar weed, though known as an annual, has been cut three times, with always a new crop appearing better than the first. Berseem is recommended for higher elevations. The tree lucern (*Cytisus proliferus*), sainfoin (*Onobrychis sativa*), and birdsfoot trefoil (*Lotus corniculatus*) were planted in December, but made little growth until late spring. All but the tree lucern set blooms and pods in May. During early June the sainfoin was attacked by the cottony cushion scale (*Icerya purchasi*), but the plants still held their vigor. In a period of seven months the tree lucern made a growth of 40 inches. The stems are slightly woody, slender, and branching at top.

SUBSTATIONS.

The work at the Kula substation was discontinued at the end of the calendar year 1913. The fall crop of Irish potatoes was a complete failure in spite of spraying. An attempt was made to try out small grains as pasture and green manure crops, the intention being to graze off these crops during the winter months and not to turn them under until time to prepare the land for corn. The crops were turned under, however, after making a good growth in early winter. That these crops will make valuable cover, pasture, and green manure crops at 3,600 feet elevation was fully demonstrated, and it is to be hoped that many in the corn-growing regions will profit by the examples shown them and grow such crops.

At the Waipio substation the agronomy department is interested particularly in a comparison of grain sorghums, Kafir, milo, and

feterita. Heretofore all such crops have failed in this location owing to prolonged drought and unfavorable soil conditions. This season the rains have been more favorable, and better results should be obtained.

SEED DISTRIBUTION.

During the year the demand for seed of field and range crops has become greater than ever before in the history of this department. While the demand for cotton seed has come particularly from the Kona district of Hawaii, seeds of velvet beans, jack beans, lupine, cowpeas, soy beans, peanuts, pigeon peas, corn, broom corn, sorghum, millets, and seeds, roots, and cuttings of lately introduced grasses have been chiefly in demand from homesteading districts throughout the islands.

REPORT OF THE ENTOMOLOGIST.

By D. T. Fullaway.

Little entomological work was done at the station during the year, on account of the absence of the entomologist. From July 1 to October 15 he was on detail with the Territorial Board of Agriculture and Forestry. An account of the work performed under its auspices is contained in a recent bulletin published by that organization.[1] From October 15 to February 28 he was on leave of absence engaged in entomological work for the Philippine government. He was away again from June 1 under the auspices of the Territory. The routine work of the office, however, has been adequately attended to and the insect collection maintained and increased by numerous additions, especially an extensive collection of Philippine insects.

Some further work has been done on the insect pests of vegetables, and there follows an account of the insects found in connection with the cultivation of cabbage, turnip, radish, lettuce, etc. Most of these are common and well-known vegetable pests on the mainland and in Europe, which have undoubtedly been introduced into Hawaii in shipments of fresh vegetables. Because of the great losses they have caused in truck farming they have naturally been the subject of many reports and bulletins elsewhere, and in Hawaii they have been dealt with in the reports of Koebele to the Hawaiian minister of the interior, in the annual reports of this station, and at some length in a report by Marsh.[2] Hardly any new or original matter, therefore, appears in this account, but in view of the economic importance of vegetable crops in connection with a growing population, which will provide a constant and ready market for all that can be produced, it is believed that the information here presented in regard to some of the drawbacks and how in part they may be overcome is desirable and will be useful to growers.

The three principal pests of crucifers in Hawaii are the imported cabbage worm (*Pontia rapæ*), the cabbage webworm (*Hellula undalis*), and the diamond-backed cabbage moth (*Plutella maculipennis*). The cabbage aphis (*Aphis brassicæ* and *Myzus persicæ*) are also bad at times. The serpentine leaf miner, cutworms, and other caterpillars of general feeding habits, as well as grasshoppers and thrips, are pests of minor importance.

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[1] Bd. Comrs. Agr. and Forestry Hawaii, Div. Ent., Bul. 3 (1914), p. 148.

[2] Marsh, H. O. [Bien.] Rpt. Bd. Comrs. Agr. and Forestry Hawaii, 1909–10, pp. 152–159.

THE IMPORTED CABBAGE WORM.

The imported cabbage worm is probably as well known as any of the insects which enter into man's domestic economy, and few fail to connect the velvety green caterpillar which feeds so freely on the plants with the large white butterfly which flits restlessly up and down the cabbage or turnip patch. The freedom with which this insect works, in fact, leaves no excuse for ignorance on this point, for often under one's very eyes the butterfly will stop and deposit on a leaf the egg from which the caterpillar later on hatches. It is one of the commonest insects, and it is rare that a cabbage plant can be grown to maturity without being attacked by it. With cabbage grown under field conditions, it becomes an absolute scourge, requiring all the ingenuity, patience, and thoroughness one can possibly develop to cope with it, and as cabbage is the only cruciferous crop cultivated under field conditions in Hawaii, the damage from this insect yearly is very large.

The insect is a well-known European species which became established in eastern Canada, presumably by introduction with vegetables about 1856. Since then it has gradually spread westward and southward in Canada and the United States, reaching Chicago in 1877, the Gulf coast in 1880, and the Pacific slope in 1883. It was first noticed in Hawaii in 1898 and is reported by Koebele [1] to have been introduced with shipments of cabbages from the coast.

The caterpillars are usually found in rather exposed positions on the leaves, which they eat through or gnaw from the edges, giving the outer ones a very ragged appearance. In cabbage which is just heading they often "worm" from leaf to leaf through the head and leave considerable frass behind, which is likely to set up fermentation and spoil the whole plant for any use. Manifestly, the time to deal with these worms is when they are young to half grown, and if the plants can be started in frames under partial cover, so that the butterfly is unable to reach them to deposit its eggs, it is possible to get them well along toward heading with little or no infestation.

The eggs are laid singly on the leaves, usually on the underside, though this is by no means always the case. They are fusiform in shape, placed on end, but with a moderately wide and firm base, are yellow and radiately ribbed, about $\frac{1}{25}$ inch high and readily seen with the naked eye. They hatch at the end of 4 days.

The larva or worm when it hatches from the egg is very small (about $\frac{1}{15}$ inch long). It increases in size rapidly, however, and at the end of 14 days is full grown and ready to pupate. At this time it is an inch or more in length and a velvety green with a yellowish

[1] Rpt. Min. Int. Hawaii, 1898, p. 87.

stripe down the middle of the back and a line of yellow spots on either side near the breathing pores.

The worm often leaves the plant to pupate in the shelter of some convenient object, but the pupa is also sometimes found fastened by a silken girdle to a leaf of the plant. It is about $\frac{3}{4}$ inch long, angular and ridged, in places somewhat spiny, green to gray, flecked with black; the frontal projection is rather long and sharp with two stout spines behind; at the tip are many closely crowded recurved hairs or spines. The pupal stage is from 8 to 12 days.

The adult butterfly has a wing expanse of 2 inches, is yellowish white, marked with black near the tips of the forewings and a black spot on the disk (two in the female); also a similar spot on the costal margin of the hind wing. It has a slow and lumbering flight, but is extremely active, especially on bright days. One female was observed to lay more than 20 eggs in less than an hour without exhausting herself.

Arsenic sprays are recommended to reduce this pest (arsenate of lead or Paris green and lime). Boiling water is also considered good. The spray must be applied to the underside of the leaves as well as the upper; the spraying outfit therefore should be provided with an extension rod.

The tachinid fly, *Frontina archippivora*, is very commonly bred from these worms and it undoubtedly does much to check their multiplication. *Chalcis obscurata* has also been bred from the pupa, and a bacterial disease is quite common among the worms.

THE IMPORTED CABBAGE WEBWORM.

The imported cabbage webworm, although much more obscure in its operations than the common cabbage worm, is nearly if not fully as destructive. It is equally prolific and just as injurious to cabbage and related crops. In fact, it is more to be dreaded than the other species on account of its peculiar habit of attacking particularly the bud, and because of its ability to escape the action of insecticides in the protection of its web. The pest is found in the Mediterranean region and generally throughout the tropical portions of the Old World. It was apparently of early introduction into Hawaii, as examples were taken by Perkins (1892–1895). It was not generally recognized as a pest in the States until 1897.

The eggs are usually laid about the bud, in the axils of the terminal leaves, oftentimes also on the upper surface of the leaves in the hollows formed by the leaf veins. They are extremely small (about $\frac{1}{50}$ inch), oval, not particularly flat, and are yellowish white flecked with reddish spots and microscopically sculptured. They hatch in from 3 to 5 days.

After hatching from the egg the young larva begins to feed on the leaves, especially the young tender leaves of the bud, and usually spins a web about itself between two leaf surfaces. Often it mines into the stalk or midrib of the leaf. The result of its work quite frequently is the complete destruction of seedling plants. Larger plants are either stunted or deformed, so that they can not make a normal growth. The worm is full grown in about 18 days, and at this stage is about $\frac{1}{2}$ inch long, fairly stout and hairy, with head black and body yellowish brown marked with a thin dark-brown stripe down the center of the back and two similar stripes on the sides, the inner of which is wider than the outer.

The worm pupates in the ground in a rather loose cocoon made of particles of soil webbed together with finely spun silk. The pupa is a quite ordinary kind about $\frac{1}{3}$ inch long, shining light brown with dark stripe on back, and a bunch of four fairly long recurved hairs at the tip. The pupal stage lasts from 10 to 15 days.

The adult moth has a wing expanse of $\frac{3}{4}$ inch, is generally gray, the forewings with darker areas about two wavy white lines which cross the disk at about one-third and two-thirds its length. They fly readily, but are more or less obscure in their habits, and are not often seen in the cabbage fields.

H. O. Marsh experimented on the control of this pest with different insecticidal mixtures, but found nothing that could be depended upon, and recommended screening the seed beds and clean culture as the only means of lessening its depredations.[1] He recommends cotton mosquito netting, but the writer has found wire netting more suitable, and the plants should be 5 to 6 inches high and have a vigorous growth before being set out. The braconid, *Chelonus blackburni*, is a very common parasite of this species.

THE DIAMOND-BACKED CABBAGE MOTH.

The diamond-backed cabbage moth takes its popular name from the peculiar diamond-like pattern of the coloration of the moth; the damage to the crop (cabbage, turnip, etc.), is done entirely by the worm, which is now almost cosmopolitan. It probably originated on the Continent, where it first came to notice as a vegetable pest. In the early fifties it was discovered in the United States; later it was found in Australia, New Zealand, South America, and in Africa, at the Cape. According to Koebele, it was an early introduction into Hawaii.

The damage to the plants caused by this pest results from the destruction of the leaves, which the worms, when present in force, quickly riddle with holes. As the species is extremely prolific, the plants are soon shattered, unless in some way protected.

[1] Chittenden, F. H., and Marsh, H. D. U. S. Dept. Agr., Bur. Ent. Bul. 109, pt. 3 (1912).

The eggs are deposited singly in large numbers on the leaves, usually in the hollow alongside a leaf-vein. They are extremely small ($\frac{1}{40}$ inch), flat, oval, lemon yellow, with iridescent, roughened surface, and hatch in 4 days.

The larva, when hatched from the egg, is very small, but increases in size gradually with age. At the end of 10 days it is full grown and ready to spin its web and pupate. At this time it is a remarkably active slender green worm, nearly $\frac{1}{3}$ inch long, somewhat constricted along the body, which bears microscopic dark spots and hairs. If suddenly disturbed it is most likely to wriggle away with some very lively contortions and drop from the leaf, suspending itself by a silken thread. It is at this period of its cycle that the insect is destructive and also most susceptible to attack with poisons, washes, etc., but its concealed position on the unexposed portions of the foliage must be taken into consideration.

The pupa, as already intimated, is partially concealed and protected by a rather unique, loosely woven, wide-meshed web, attached on all sides to the surface of the leaf. It is a little less than $\frac{1}{4}$ inch long, slender, greenish yellow to pale brown, with a few small tubercles on the head and a bunch of spiny hairs at the tip. Within it the moth develops in from 6 to 8 days and emerges by bursting through the anterior end of the case and its web.

The moth is about $\frac{1}{3}$ inch long with the wings closed and measures $\frac{1}{2}$ inch across when these are spread out. It is generally an ashy gray. The forewings, however, are flecked with black on the disc and apex and have a wide black streak extending from the base through the middle for about half their length. Between this area of black and the hind margin the wing is creamy white, the line of separation usually somewhat wavy. The hind wings are a glossy leaden gray, the antennæ and underside of the body almost white.

Sprays are recommended to reduce the damage of this destructive worm in cabbage and turnip fields, and the remedies commonly used for the other cabbage worms (arsenic, kerosene emulsion, and hot water) are effective for this pest as well. The multiplication of the insect is also greatly checked by the hymenopterous parasites, *Limnerium blackburni*.

These three species, which have been especially mentioned, are all, with regard to their food plants, confined entirely to crucifers, although my observation from the beginning has been that the injurious effects in the case of each species are more noticeable in some crops than in others. Thus the cabbage worm (white cabbage butterfly) does more damage to cabbage than to other crops, although turnips and cauliflower are also attacked. The worm of the diamond-backed moth is most injurious to thin-leaved plants and seedlings; on the tough rubbery leaves of cabbage it has hardly any

effect. The webworm does greater damage to root crops—radishes and turnips—on account of its habit of eating out the bud. It also destroys the foliage of thin-leaved plants.

OTHER PESTS OF CRUCIFERÆ.

The best known aphid in connection with crucifers is the common cabbage louse, *Aphis brassicæ*, but in Hawaii this species is much less numerous than another, *Myzus persicæ*, which on the mainland and in Europe is found principally in connection with the peach. The two species are entirely dissimilar, the latter being a naked green louse, while the former is always covered with a whitish mealy coat. The injury inflicted by aphids results from the withdrawal of the cell sap of plants, causing the rapid withering of the leaves, which may be a mere temporary disturbance or fatal, depending on the extent of the infestation. Both species here are effectively controlled by a hymenopterous parasite (*Diæretus rapæ*) and the dry tumid bodies of parasitized individuals are a common sight on the outer leaves of any crucifer. Aphids, therefore, would be considered a negligible factor in the cultivation of cabbage and related crops were it not for the fact that peculiar weather conditions in Hawaii sometimes favor the rapid multiplication of these pests and occasionally seed-bed plants become badly infested with *Myzus persicæ* so that the plants are greatly retarded or killed outright. These infestations may be promptly remedied by spraying the plants with whale-oil soap (1 pound to 5 gallons of water), blackleaf 40 (1 fluid ounce with 3 ounces of whale-oil soap and 4 gallons of water), or miscible oils (directions for the application of which usually accompany the containers).

The serpentine leaf miner is extremely conspicuous in vegetable gardens where thin-leafed crucifers, such as turnips, daikon, shirona, etc., are growing, but is of no great importance as a crop pest on account of the trivial nature of its injuries and its heavy parasitization. It has recently been studied in the United States by the entomologists of the Department of Agriculture, who found that the same insect previously known under several different names attacks a wide variety of plants. It does the same here, and has been found in geranium, nasturtium, and beets in addition to many cruciferous and leguminous crop plants. The insect is a common European pest which has spread eastward into Egypt and westward upon the American Continent. The damage it causes, as already indicated, is slight and comes from the injury to the foliage caused by the mines of the larvæ or maggots. The eggs are laid deep in the mesophyll of the leaf, are white, oval, and almost microscopic in size ($\frac{1}{100}$ inch). They hatch in 4 days. The larva begins its mine from the position of the egg and its progress is indicated by a bleached wandering track

which enlarges with the growth of the maggot and may end in a pocket. The larva is a slender, shining, yellowish maggot about one-eighth inch long when full grown, with spiracular protuberances and black oral appendages which are almost constantly in motion, rasping away the mesophyl. It continues feeding and advancing in the leaf until it is ready to pupate, usually for 9 or 10 days; then it leaves the leaf end and enters the soil. The pupa is inclosed in an oblong, oval puparium about one-twelfth inch long, distinctly segmented, brown, and with prominent spiracular openings in front and behind. The insect remains in the pupal stage for 6 days, at the end of which the perfect insect emerges. This is a small black and yellow two-winged fly so commonly seen hovering about the cabbage patch. The cycle of the fly in Hawaii according to the above data, which were obtained in April, requires from 20 to 25 days. There would probably be some acceleration of the development in the summer and a slight retardation in the winter months.

Three hymenopterous parasites have been bred from the species belonging to the genera Derostenus, Diaulinus, and Chrysocharis. These are usually active enough to keep the pest well checked and no remedial measures are suggested or considered necessary.

Several species of thrips are also commonly found on crucifers but can not be considered of much importance from the growers' standpoint. The commonest is the onion thrips (*Thrips tabaci*), a pale species. Less common is a dark species of Chirothrips.

Cutworms are also occasionally found and are the common garden species which have been repeatedly reported as attacking succulent plants indiscriminately (*Agrotis ypsilon*, *A. crinigera*, and *Caradrina exigua*). A few other leaf-feeding caterpillars have also at times been encountered. *Hymeria fascialis*, *Plusia chalcites*, and the long-horned grasshopper (*Atractomorpha crenaticeps*). All these are adequately controlled by parasites and are not particularly injurious, but if so at all, their prevalence is in the nature of an outbreak which can scarcely be foreseen, is easily checked by arsenic sprays, and at all events is not likely to be of long duration. The melon fly (*Dacus cucurbitæ*) has often been reported infesting the heart of cabbage, but the infestation is not at all common and is considered to be due to abnormal conditions in the plant, and of a secondary nature.

One of the principal sources of trouble in growing cruciferous crops is the absence of clean cultivation. Specific measures of control have been advised in the case of each of the pests above discussed, but these measures relate to infestations which already prevail. Unfortunately, also, they entail considerable labor and expense and are often partly or entirely ineffective. In many cases, moreover, the conditions would be very different if clean cultivation

had been constantly practiced. This applies particularly to the control of the more insidious pests and to districts where cruciferous crops are raised continuously from year to year. In such places the production of cruciferous crops with profit after a time becomes almost an impossibility owing to the cumulative factor in the natural increase of the pest concerned. It is therefore desirable that when the crops are taken off the stumps be pulled and these together with discarded leaves and all other trash in the fields be disposed of so that the insects in them are unable to breed out. This might be accomplished by deep plowing, though the results would undoubtedly be better if the trash were burned or buried several feet below the surface of the ground. This measure is almost essential in dealing with hardy insects in a country where breeding goes on throughout the entire year, and would take the place and bring about the beneficial results in the way of insect destruction attending the long seasons of low temperature in more northern latitudes.

REPORT OF THE SUPERINTENDENT OF THE RUBBER SUBSTATION.

By W. A. Anderson.

The most important developments at the rubber substation were in connection with observations on the latex-bearing qualities of individual trees, the possibility of propagating for these properties, and the suitability of roselle as an intercrop for rubber.

PLANTING CUTTINGS.

The wide variation in the yields of individuals among Ceara (*Manihot glaziovii*) rubber trees, suggests the possibility of developing a plantation by propagating from exceptionally good yielders with a view to eliminating this wide variation, and obtaining a stand on which all the trees will be large yielders. Seedlings can not be depended upon to come true, and, consequently, in 1912, an experiment was planned to determine the feasibility of transmitting high yielding properties through cuttings.

In February, 1912, 200 cuttings of various size were taken from trees that were considered good yielders, and planted on land belonging to The Hawaiian American Rubber Co., in Nahiku. During 1912 broom corn was planted among these trees, and in 1913, roselle, so that they have been fairly well cultivated during the two years. In January, 1914, when the trees were 1 year and 11 months old, they were tapped with a single cut. The new growth on these trees, 1 foot above the original cutting, averaged 10.8 inches in circumference. They yielded 16 ounces washed rubber from one tapping, of one cut per tree. This is equal, in both yield per tree and returns for labor, to the average reported from 6-year old trees unselected, tapped in 1912. The yield from the different trees was more uniform than on the plantations as a whole, and the results indicate that this method of propagation can be successfully employed to transmit desirable latex-yielding properties.

It was also observed, in tapping experiments on 7-year old trees in the fall of 1913, that the best trees yielded as high as 2 ounces wet rubber at one tapping equivalent to about 1.36 ounces dry rubber. By the method employed in obtaining this yield, one man averaged 200 trees, tapping and collecting, per day's work. The number of

these high yielding trees is small, averaging probably not more than one or two per acre over all the plantations. If all the trees yielded in this manner, rubber could be collected at the rate of 17 pounds dry rubber per man a day. At $1 per day, the average wage for tapping, the rubber would cost about 6 cents per pound for tapping alone. Factory expense, packing and shipping, freights, insurance, and commissions should not exceed 15 cents per pound, and in large quantities could be made much less than this. Other overhead charges would depend on the amount of rubber produced, and can be estimated only on the basis of the number of trees tapped and the yield per tree per year. However, at these figures, there would seem to be a fair margin of profit, even at the present price of rubber.

This high yield of the best trees, coupled with the indication that the high-yielding properties can be transmitted through cuttings, suggests a method by which Hawaiian rubber can be produced at a profit even with low prices for the product. By discarding all unprofitable trees, and planting cuttings from these few best trees, plantations can be developed from which rubber can be obtained at a low tapping cost. This experiment at its present stage, indicates only that the trees obtained from cuttings in this way will give more uniform and larger yields than can be obtained from the ordinary methods of planting with seedlings. Whether trees raised from cuttings taken from trees yielding 2 ounces per tapping, will likewise yield 2 ounces per tapping, can be determined only by keeping a record of the trees from which the individual cuttings were made, and comparing the yield from the resulting trees when they shall have reached the age of the parents at the time the cuttings were taken. As the trees from which 2 ounces per tapping was obtained were seven years old, it would take seven years to determine this point definitely. However, since the yield from these 2-year old cuttings equalled the average yield from ordinary 6-year old trees, it would seem reasonable to assume that it was approximately as large as that of the present trees at two years of age. It will be interesting at least to watch these young trees and to note their performance at maturity.

ROSELLE.

Roselle (*Hibiscus sabdariffa*) was planted on a commercial scale between the rubber trees on two of the plantations during 1913. Results indicated that, with a market for the fresh fruit at 3 to 4 cents a pound, this would be a profitable intercrop. At present, however, there is practically no market for the fresh fruit while a limited market does exist for the dried fruit at 30 to 40 cents per pound, which is equivalent to $2\frac{1}{2}$ to $3\frac{1}{3}$ cents per pound for the fresh fruit less the cost of drying.

Even at this price, however, the results of last year's experiment were so promising that five farmers besides two of the rubber plantations are planting this year, with a total area of about 220 acres.

The rubber trees among which the roselle was planted were spaced 10 by 20 feet. The roselle was accordingly planted 5 by 5 feet as the most convenient spacing to utilize the soil in conjunction with the trees. This is rather close planting where the bushes grow as large as in the Nahiku district. In the early plantings on the lower elevations, the plants grew to a height of 8 to 10 feet, bearing the fruit rather too high for convenient picking. These plants yielded, however, at the rate of 10 pounds of fruit per plant, or roughly, 15,000 pounds per acre among the rubber trees. With the same yield per plant, and the rubber trees replaced by roselle plants, we should have had over 17,000 pounds per acre, which is a larger yield than has been elsewhere reported.

During the same year a planting of 25 acres was made in the Kona district of Hawaii, under the supervision of Mr. R. V. Woods, of the Kona Kanning Ko., who reported the results as indicating that, while planted as a catch crop among other things it might prove profitable, it was not profitable as a crop by itself. The failure in Kona was no doubt partially due to the unusually dry season during the period of growth, while the copious rainfall in Nahiku may be partially responsible for the highly satisfactory yield in this district. During the eight months from the time the first seed was planted to the time of harvesting, the precipitation amounted to 109.17 inches. The partial protection from the trade winds afforded by the rubber trees among which they were planted may also have helped to increase the yield. Whatever the causes, the results would indicate that the Nahiku district is well suited to the growing of this fruit among rubber trees.

Considerable difficulty was experienced in drying the fruit. It was at first thought that the drying could be done at ordinary temperature in a drying house built according to the plan given for a tobacco drying house.[1] Harvesting began in November, and during this month 26 inches of rain fell. It was found the fruit would not dry without artificial heat. Consequently, the drying house was equipped with steam heat. While the building was poorly adapted to this method it was found that, at a temperature of 120 to 140° the fruit would dry bone dry in 24 to 48 hours. The proportion of fresh fruit to dried was roughly the same as previously reported from the experiment station grounds in Honolulu.[2]

Picking is the most expensive operation in connection with the handling of the crop. At first the fruit was picked and carried com-

[1] Hawaii Sta. Bul. 15.

[2] Hawaii Sta. Rpt. 1909, p. 55.

plete to the drying house, where it was seeded into the drying trays. It was found cheaper, however, to remove the seed pod in the field at the time of picking. This avoids one handling of the entire weight of the fruit, and saves about one-third in the weight that must be transported to the drying house. At the same time, it avoids another handling of the seed pods, which must be removed from the drying house after seeding by the first method, and leaves the green seeds and pods on the field for whatever fertilizing value they may have. With the price of labor averaging $1 per day, it cost 2 cents per pound of seeded fruit to harvest the crop in this way. The saving in handling and transportation was the chief advantage of the second method.

Considerable loss was experienced from cutworms, both in the nurseries and after transplanting. This has been largely avoided this year by protecting the nurseries with ditches, planting as much as possible between the cutworm seasons, and allowing the plants to remain longer in the nurseries before transplanting. Not only the planting in nurseries, but the transplanting should be done between the cutworm seasons as far as possible. If not planted too thickly in the nurseries, the seedlings can be allowed to reach a height of $1\frac{1}{2}$ to 2 feet before transplanting, without serious injury. This has a tendency, however, to make them branch high, and a better size for transplanting is 6 inches to 1 foot. With the seedlings ready in the nurseries, a few can be transplanted and watched a few days for evidences of cutworms. When it is found that the cutworms do not attack these, the transplanting can be done with comparative safety. Losses from this source this year have been negligible.

The work on this crop has shown:

(1) That large yields can be obtained in this locality when planted between rubber trees;

(2) That some means must be provided for drying artificially;

(3) That unless precautions are taken cutworms will cause serious losses, but that this loss can be largely avoided; and

(4) That if the work is all done by hand with tools now available, the crop can be most economically handled by picking and seeding at one operation in the field.

The value of the crop planted this year by five farmers and two rubber companies is conservatively valued at $52,800.

There is some indication that certain of the plants, by proper handling and judicious pruning, can be made to grow and bear a second year. This would seem to be a proper subject for further investigations.

EFFECT OF FERTILIZERS ON THE YIELD OF RUBBER.

The object of this experiment was to determine the advantage, if any, in the use of the ordinary fertilizers to increase the yield of rubber during a tapping season. A block of 1,000 trees was divided into 10 plats, numbered 1 to 10. The odd sections were left unfertilized for check, and the even sections fertilized with equal amounts of phosphoric acid in the form of superphosphate, potash in the form of potassium sulphate, and nitrogen in the forms of sodium nitrate and ammonium sulphate. The trees were measured at the beginning and at the end of the experiment. The sodium nitrate was divided into four applications, but rainy weather destroyed the results of the tapping after the last application, so that the results are tabulated for only three series of tappings with three-fourths of the nitrate.

Ten tappings were made during September, October, and November, and five during February. Sodium nitrate was applied just before each of the tappings. In the three series of tappings, results per tree were as follows:

Effect of fertilizers on yield of rubber.

Plat No.	Fertilizer.	Yield.
		Ounces.
1	No fertilizer	1.54
2	Superphosphate, 375 pounds, and potassium sulphate, 125 pounds	1.57
3	No fertilizer	1.1
4	Superphosphate, 375 pounds; potassium sulphate, 125 pounds; and ammonium sulphate, 375 pounds	1.4
5	No fertilizer	1.32
6	Superphosphate 375 pounds, potassium sulphate 125 pounds, and sodium nitrate 375 pounds	1.4
7	No fertilizer	1.43
8	Ammonium sulphate 375 pounds	1.55
9	No fertilizer	1.44
10	Sodium nitrate 375 pounds	1.48

Comparing the yield per tree from each of the fertilized plats with the average from the two unfertilized plats on either side, plat 2 exceeded plats 1 and 3 by 19 per cent, plat 4 exceeded 3 and 5 by 15 per cent, plat 6 exceeded plats 5 and 7 by 5 per cent, plat 8 exceeded plats 7 and 9 by 8½ per cent, and plat 10 exceeded plat 9 by 3 per cent. Had all the scrap been collected, the nitrate fertilized plats would have made a better comparative showing. The trees on these two plats retained more rubber after each tapping that had coagulated on the trees. This was more noticeable in the case of plat 10, fertilized with nitrate alone.

GLENWOOD SUBSTATION.

In Olaa comparatively few days go by without rainfall. In upper Olaa it is not uncommon for a month to pass with but a half dozen glimpses of the sun. From April 1 till June 30, 1914, eight acres intended for spring planting at the substation lay fallow waiting for suitable weather to render it dry enough to harrow. This is not at all an uncommon occurrence in Olaa as elsewhere on the windward sides of the larger islands, at elevations above fifteen hundred feet. Nevertheless, periods of several weeks will elapse when sunny skies and slight precipitation prevail. There is, however, no definite dry or wet season and all empirical rules regarding the weather probabilities are very uncertain. The conditions are so different from European and American conditions, that there is little recorded experience available to aid in developing a system of agriculture suited to this region.

Farmers in Olaa are adopting a system of agriculture apparently suited to the climate. The popularity of soiling crops such as honohono (*Commelina nudiflora*) and Para grass can be accounted for by the fact that they are perennial and require little cultivation other than top-dressing with manure. Their use is becoming general where any attempt at all is made to supplement the natural pastures by green crops. It is probable that an extension of the present crude system of live-stock farming with honohono and Para grass as the main crops, could be made very profitable. In the summer months there is much more growth than during the winter. Honohono lodges badly and Para grass becomes woody if left in the field after a certain stage of development. To prevent loss of the surplus in summer, some means of storing is needed. The silo offers one means of solving this difficulty. A hay-drying kiln, either under cooperative or individual ownership, would offer an additional means of storing feed, and would also make Para grass hay a possibility. Since practically all the hay used in the Territory is imported it would seem that a ready market is at hand for a great deal of hay which could thus be a by-product of the live-stock farms of this region. The care of manure is a problem that requires study. There is little available litter to be used as an absorbent. It is consequently difficult both to keep cattle clean in the stable and to absorb the liquid manure to make it convenient to handle. Some dairymen are saving the liquid which is voided while the stock are in the stable by running it into barrels and then carrying it out in buckets. While this means is effective it needs modification in the interests of economy of labor. The matter of economical methods of handling this valuable by-product of the live-stock industry merits attention, since the difference between profit and loss in manufacturing and

agricultural industries largely depends upon the advantageous utilization of the by-products.

An island-bred mare of good medium heavy type was purchased in July. The prime object in buying her was to secure a work animal. She has been bred to a large standard-bred stallion.

CATTLE.

During the year the station herd of cattle was increased by the birth of two bull and two heifer calves, all pure-bred Guernseys, eligible to registry. The herd bull, Raymond of Alta Vista, has stood for service throughout the year. All the farmers within reach have taken advantage of this opportunity. A census of the calves in the neighborhood shows that there are 15 grade heifers sired by the substation bull, distributed among 9 different owners.

POULTRY.

In January a small flock of Rhode Island Red chickens was purchased. White Leghorn eggs were also purchased and hatched in an incubator and the chickens reared indoors in deep litter brooders. It is intended to increase the flock of poultry this year, to study problems connected therewith, and by trap-nesting to develop a high egg laying strain in order to supply farmers with more productive laying stock. A small flock of White Muscovy and another flock of Indian Runner ducks has also been purchased.

CREAMERY.

It had been hoped that the cooperation of all the dairymen within reach could be secured for the Glenwood Creamery Co., which was organized with the assistance of the substation. This cooperation was not secured. Sufficient interest had not been developed among the patrons in delivering sweet cream and the grades established proved to be too low. During the warm months of summer the butter lacked keeping quality and the best prices were not secured. It was proved, however, that sweet cream could be delivered without the use of ice by attention to cleanliness and promptly cooling cream to air temperatures. The output of the creamery was only half of what has been hoped for. This made the cost of manufacture double what was expected. It became apparent, therefore, that it was not advisable to continue operating the creamery as a cooperative enterprise. The company therefore resolved itself into a cooperative marketing association in December. To date it has been doing satisfactory work as a cooperative marketing and buying association, and the field of its operations is extending. Ultimately, it may establish a creamery when circumstances justify it. The substation

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has rendered it special assistance, because it is a pioneer organization of its kind so far as Hawaii is concerned. It is now so well established that the assistance of the substation is no longer required.

The substation has bought cream from a few neighboring farmers and is making butter to study problems which arise in connection therewith. The butter made is marketed through the creamery company.

CORN AND SORGHUM.

Three acres of corn of the native white variety from Waimea were grown for the silo. A representative row in this field was weighed and produced at the rate of 8.5 tons per acre. Two acres of Early Orange sorghum were grown for the silo. A representative plat of the field was weighed and produced at the rate of 12.5 tons per acre. Part of the sorghum field was allowed to ratoon, and was used for green fodder as required.

GRASSES.

Para grass maintains its lead as the most promising grass for pasture or soiling purposes.

Giant water grass, Natal grass, Italian rye grass, orchard grass, and redtop have all done well and would probably be valuable as pasture grasses.

The area of honohono for soiling purposes has been increased as rapidly as the supply of stable manure permitted. There is now about a half acre which is being cut for stable feeding, daily, and top-dressed with manure after each cutting. Records of the yield are being kept in order to make comparisons with Para and other grasses.

LEGUMES.

Soy beans were sown broadcast on the corn stubble in November. A very poor stand was secured, which was plowed under in January and the ground planted to wheat and kidney beans. These produced a light growth, which was plowed under in March, as green manure. No satisfactory results were secured from any legumes.

EXTENSION WORK.

During the year assistance was rendered in the organization of two associations of cane planters. One was the East Hawaii Cane Planters' Association, an organization of English speaking cane planters, and those interested in sugar cane. The purpose of the organization was to assist in matters of interest mutual to the members of the association. It is intended to work along the lines adopted by farmers' clubs elsewhere.

A federation of associations similar to the above was also formed. This federation adopted the name of "Hilo-Puna Cane Planters' Union." It aims to federate all associations of cane planters, regardless of language and locality. The unit organization paid into the union assessments at the rate of 30 cents per year for each acre cultivated or controlled by the individual members of the associations. The fund thus raised is being used to secure expert assistance from legal and chemical advisers in connection with difficulties that arise in regard to the marketing of sugar cane. The charter members of the union are the Hakalau Sugar Planters' Association, the Wainaku Sugar Planters' Association, the Honomu Sugar Planters' Association, and the East Hawaii Cane Planters' Association. The union is accomplishing much good by overcoming causes of friction between cane planters and mill managers.

During the year six talks were given to the classes in agriculture at the Hilo Boarding School and the Hilo High School.

SILO.

In September a concrete pit silo was built, 12 feet in diameter, and 12½ feet in depth. The bottom is 4 feet below the level of the stable and the top level with the top of the bank at the rear of the stable. This was filled twice, in October and February. A 7-inch hand-power feed cutter, equipped with a pulley and driven by a 1½ horsepower gasoline engine, was used to cut up the fodder. The feed cutter was placed on timbers across the top of the silo so that the cut fodder fell from the machine directly into the silo.

In October the silo was filled with corn, sorghum, and Para grass; in February it was filled with sugar cane, sorghum, and Para grass. Special interest is attached to the ensiling of sugar cane and Para grass, as the use of these two crops in the silo is comparatively new. Sugar cane made excellent silage, very sweet, little more acid than corn silage, with very agreeable odor, and was readily eaten by the stock. Para grass, mixed with a little honohono, also made silage which the stock ate readily, though of a less agreeable odor than other standard silage crops. Both of these crops are big yielders and are promising for cattle feed.

In June a 20-foot redwood silo was placed on top of the concrete silo already in use. This made a silo 32½ feet deep by 12 feet in diameter. This was filled with cane tops in June in cooperation with the Olaa Sugar Co.

THE COMPOSITION OF HAWAIIAN FRUITS AND NUTS.

By Alice R. Thompson, *Assistant Chemist.*

INTRODUCTION.

The analyses on which this report is based were made to gain information upon the chemical composition of the common fruits and nuts which occur in the Territory. The station receives frequent requests for information regarding the composition of ripe fruits of various kinds and regarding the changes in composition which take place during ripening. Almost every fruit consumer has preconceived notions or desires to know more about the nature of his favorite fruits, their nutritive value and possible physiological effects.

Many of the fruits studied by the station have been previously analyzed, but few of these analyses are based on Hawaiian specimens. Moreover, the analyses were made in various parts of the world, in many cases, from fruits which had been shipped long distances in cold storage. The results thus obtained are not strictly comparable, one with another, for the reason that they were obtained by various chemists and by various methods. The variations observed in the published analyses of a given fruit are due to differences in climatic and soil conditions, stage of ripeness, degree of freshness of the fruit, method of analysis, and perhaps to other factors. The analyses reported were all made by the writer according to one uniform method. All the fruits and nuts came from one locality. Only normal, fully ripe fruits were used. They were picked in the morning and analyzed on the same day. The results, therefore, reliably represent the relative percentages of various constituents in an unusually large list of fruits and nuts from one locality.

In the case of the mango, avocado, papaya, and citrus fruits, several varieties of each were analyzed. Interesting variations in the composition of varieties of the same species were found.

The chemical changes which take place during the ripening of fruits are of great interest from a scientific as well as from a practical standpoint. The station had previously studied the ripening of pineapples. A similar study was made of bananas and papayas. Interesting data on the ripening process in these two fruits are herein presented.

METHOD OF ANALYSIS.

The analytical methods employed were essentially those of the official chemists. The total solids were determined by mixing with asbestos and drying at 100° C. In a few cases it was found difficult to determine insoluble solids when the soluble solids were very slow to filter through the linen filter. The fruit sample began to jelly before it all passed through. Usually the determination was made without this difficulty. Acid was determined by titration against fifth-normal KOH, using phenolphthalein as indicator in the uncolored solutions; otherwise litmus paper was used. In clarifying the fruit solutions for sugar determination alumina cream was used in the analyses recorded in the tables on mango and papaya. In all other cases lead subacetate was used instead, since alumina cream proved inefficient in these fruits. Reducing sugars were determined by the volumetric Fehling solution method of Munson and Walker, the more acid fruit solutions being neutralized. Sucrose, with a few exceptions, was determined by Clergat's method. Fat was obtained by extraction with ether. When starch was known to be an especial constituent the total hydrolyzable carbohydrates were determined by acid hydrolysis. Diastase was used in the starch determination in studying the ripening of bananas and papayas.

ANALYTICAL DATA.

In the table on page 66 is shown the composition of several varieties of mangoes. The total solids are high for the average fresh fruit; the total sugars vary from 11 to 20 per cent, according to the variety. In all samples the sucrose is the principal sugar present. The protein in several varieties is a little higher than is usual in fruits. The acidity varies and is as much as 0.5 per cent in one variety.

Qualitative tests showed the presence of considerable amounts of tannin, but no starch was apparent.

The analysis of the avocado shows it to contain rather high total solids. The high percentage of soluble solids is probably due in part to oil which passed through the linen filter. The protein and ash are high for fruit. Very noticeable are the small amounts of sugars and the large amount of fat. The fat varies in the several varieties, being as high as 21.79 per cent in one fruit. The acid content of the fruit is very low.

As the composition of the banana is discussed more in detail later little need be said here about the analyses. They show the high and variable sugar content of the ripe banana, being highest in the baking varieties. The ash and protein are high. The acidity is low, being highest in the Apple banana.

The breadfruit is included in the table with bananas because it contains such high amounts of carbohydrates. In comparing it with the banana the hydrolyzable carbohydrates are seen to be much greater in amounts. The breadfruit contains considerable amounts of starch even when ripe. The ash, fiber, and protein are high.

The Samoan breadfruit was analyzed at a riper stage than the Hawaiian specimen, which may account for the larger proportion of starch to sugars in the former.

The jack fruit, belonging to the same family with breadfruit, and curious because of its huge size and strong peculiar odor, is rather high in protein and fiber and low in acid. The analysis of the total pulp shows less sugar than that of the edible portion, which consists of a yellow custard-like pulp surrounding each seed. The seed of the jack fruit has a very high content of starch and but very little sugar. The protein is over 5 per cent.

The composition of the papaya is discussed below in more detail. In comparing the several varieties the total solids are seen to vary several per cent.

The acidity and protein vary also with the variety as do the sugars. As experiments in breeding new varieties of papayas are being carried out by the horticultural department of this station to develop flavor, sugar, and firmness, these analyses are of interest as showing the changes brought about. It will be noticed that the principal sugar of the papaya is invert sugar, and only traces of sucrose are found.

Citrus fruits are known for their high acid content, which makes them especially refreshing when made into beverages. The common orange is milder than the lime or lemon, containing less acid and more sugar than the latter fruit. Sucrose and reducing sugar are both present in the orange.

The fiber is rather high in the oranges and shaddock. The high fat content in the limes and lemons may in part be due to oil from the skin. The samples were prepared by peeling off the skin in case of the orange and grinding up the whole pulp. The lemons and limes were squeezed as in obtaining the juice, which accounts for the low total solids found.

The samples of guavas analyzed were obtained by grinding up pulp and seeds together, as it is difficult to separate the seed. The skin was removed in all except the strawberry guavas, which are eaten whole.

The sugar content of the guava is not high. The strawberry guava contains more acid than the other varieties, but is less acid to the taste.

The sweet sop and cherimoya contain considerable sugar, principally reducing sugar. The protein and fiber are high and the acid low.

The roselle is of commercial interest, as it is used to a great extent in making jams and jellies which resemble cranberry jelly. The calyx is unusually low in sugars and hydrolyzable carbohydrates and quite high in acid. Its food value is almost nil, but its strong acidity, fine red color, and jellying qualities make it of especial value as a cooking fruit. The seed pods have a somewhat higher carbohydrate content and are less acid.

The tamarind is of interest because of its high acid and sugar content. It is supposed to contain more acid and sugar than any other fruit. The tamarinds analyzed in this laboratory were lower in reducing sugar than those grown in the Philippines, but the fruit may have been slightly green. The analysis reported by Pratt and Del Rosario [1] shows the green tamarind to contain little sugar, but the sugar increases very greatly on ripening.

In the analysis of the pomegranate, sample 1 was obtained by grinding up the pulp and seeds, but in sample 2 the seeds were separated from the pulp.

Of the Hawaiian berries the poha and Hitchcock berries are most commonly used. The poha makes a jam which has an unusually delicious flavor. The berries are quite acid. The ohelo grows wild on the mountain sides and is not cultivated to any extent. It has a low sugar and acid content. The Hitchcock berry is similar to the raspberry.

Prickly pear grows wild on the islands, but the red juicy fruit is not very popular as a food on account of the spines that make it difficult to pick. The fruit is juicy, sweet, and very mild in flavor.

Kamani fruit is used in making an alcoholic liquor, and is very fibrous.

The noni is a bitter fruit with a disagreeable odor; it is much used as a medicine.

Of the nuts analyzed the coconut and kukui are best known. The nuts contain considerable oil and but little sugar. The protein is high in the kukui and cashew nuts, but low in the coconut. The kukui is only eaten in small amounts, as it has a poisonous effect. The cashew requires baking before it can be eaten with impunity.

The table following gives the results of the analyses of 92 samples of Hawaiian fruits and nuts.

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[1] Philippine Jour. Sci., Sec. A, 8 (1913), No. 1, pp. 59–80.

Composition of some Hawaiian fruits, nuts, etc.

Kind of fruit.	Edible portion.	Waste.	Total solids.	Insoluble solids.	Ash.	Acids as H_2SO_4.	Protein.	Sugars.			Polarization.			Fat.	Fiber.	Hydrolyzable carbohydrates other than sucrose.
								Reducing.	Sucrose.	Total.	Direct.	Invert.	Temperature.			
Mango (*Mangifera indica*):	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	°*V.*	°*V.*	°*C.*	*Per ct.*	*Per ct.*	*Per cent.*
Pirie	60.00	40.00	20.52	3.14	0.343	0.221	0.456	3.55	11.23	14.78	+ 8.84	−5.45	31	0.032	0.508	.....
Pirie	65.28	34.72	21.02	1.75	.466	.127	.838	3.31	14.02	17.33	+11.8	−6.10	30	.165	.404	.....
Alphonse	67.48	32.52	20.92	2.42	.469	.373	.919	3.74	10.90	14.64	+ 9.7	−4.2	30	.149	.715	.....
Oahu	61.66	38.34	19.61	3.82	.445	.122	.531	2.06	13.66	15.72	+12.4	−4.8	33.5	.....	.713	.....
Totafari	60.19	39.81	15.27	2.11	.277	.578	.475	3.55	7.93	11.48	+ 4.8	−5.2	33.5	.065	.539	.....
Jamshedi	66.25	33.75	20.07	4.35	.415	.264	.944	1.53	11.53	13.06	+10.2	−4.4	32	.133	.656	.....
Gay	59.60	40.40	23.42	4.02	.419	.379	1.075	3.01	16.99	20.00	+14.2	−7.2	33.5	.530	.695	.....
Brindabani	69.75	30.25	19.75	5.88	.274	.269	.438	4.55	10.43	14.98	+ 8.0	−5.2	32.2	.126	.518	.....
Avocado (*Persea gratissima*):																
Makaha I	74.57	25.43	21.01	10.43	1.003	.137	1.456	.83	.00	.83	+ 2.0	+2.4	31.4	13.05	1,282	.....
Makaha II	73.47	26.53	25.87	13.97	1.031	.093	.....	.64	.00	.64	+ 3.2	+3.2	31.5	17.25	1.378	.....
Davis No. 7	64.57	35.43	21.29	13.78	.915	.069	2.094	1.28	.39	1.67	+ .5	.0	33	11.92	1.639	.....
Davis No. 6	51.34	48.66	30.74	20.57	1.038	.078	1.700	.44	.00	.44	+ .2	+ .2	31.8	21.79	1.672	.....
Davis No. 4	63.39	36.61	28.15	18.91	1.034	.104	2.238	.56	.00	.56	+ .6	+1.2	30.5	19.01	1.707	.....
Banana (*Musa* spp.):																
Chinese	70.00	30.00	21.28	2.45	.955	.245	1.788	8.18	8.48	16.66	+ 7.9	−3.2	23.7	.180	.253	None.
Apple	74.49	25.51	31.52	.....	.964	.417	1.238	14.56	9.59	24.15	+ 6.6	−5.6	31	.223	.351	.....
Brazilian	68.25	31.75	27.78	7.21	.924	.406	1.775	17.23	2.45	19.68	− .9	−4.0	31.5	.201	.305	2.57
Baking	75.72	24.28	32.22	5.49	.750	.397	1.350	21.16	5.04	26.20	+ 1.6	−4.8	31.6	.518	.333	2.53
Fehi	64.29	35.71	27.87	10.30	.....	.230	1.069	14.49	.00	[1] 14.49	.....	.....	.....	.046	.594	.....
Breadfruit (*Artocarpus incisa*):																
Hawaiian	77.75	22.25	41.82	20.35	.952	.049	1.575	1.75	7.74	9.49	+ 8.2	−1.6	32	.190	1.204	27.89
Samoan	83.44	16.56	26.89	8.44	1.152	.078	1.575	4.93	9.67	14.60	+10.4	−2.0	29	.517	.978	9.21
Jack fruit (*Artocarpus integrifolia*):																
Whole fruit	57.73	42.27	18.92	8.86	.962	.181	1.688	5.55	2.18	7.73	+ 1.6	−1.2	29	.599	1.904	.....
Pulp	32.00	68.00	23.20	5.76	.934	.274	1.444	6.51	8.64	15.15	+ 7.5	−3.6	28.5	.450	1.311	.....
Seeds	87.00	13.00	50.82	34.94	3.497	.162	5.444	.71	1.16	1.87	+ 1.9	+ .4	28.0	.241	1.609	23.53
Papaya (*Carica papaya*):																
Trinidad (2976)	75.56	24.44	12.14	1.66	.539	.061	.438	8.98	.74	9.72	+ 1.8	+ .86	31	.065	.780	.....
South Africa (2973)	72.29	27.71	13.00	2.32	.549	.098	.681	10.20	.53	10.73	+ 2.4	+1.7	29.2	.074	.818	.....
South Africa (2973)	73.50	26.50	14.06	2.52	.612	.098	.519	10.62	None.	10.62	+ 1.8	+1.76	33.4	.041	.851	.....
Honolulu (2355: 3)	71.75	28.25	12.20	1.81	.560	.078	.500	10.29	None.	10.29	− .4	− .5	31.5	.059	.663	.....
Barbados (2848)	84.11	15.89	11.72	2.44	.481	.069	.463	8.95	None.	8.95	+ .8	+ .86	32.5	.068	.765	.....
Tahit (2975)	74.76	25.24	10.19	2.07	.677	.171	.906	7.50	.94	8.44	+ .7	− .5	31.5	.045	.789	.....
Tahiti (2975)	78.14	21.86	9.50	1.90	.630	.113	.694	6.71	.39	7.10	+ .7	+ .2	30.0	.....	.....	.....
Barbados (2764)	77.47	22.53	10.58	1.88	.517	.103	.731	7.47	.31	7.78	+ 2.0	+1.6	31.0	.055	.754	.....

Barbados (2848)	82.44	17.56	9.22	1.99	.372	.078	.519	6.10	.31	6.41	+ 2.0	+1.6	30.8	.091	.842	.....
Panama (2979)	47.71	52.29	16.51	1.78	.878	.186	.750	13.21	2.04	15.25	+ 1.0	−1.6	31.0	.115	1.003	.....
Panama (2978)	48.58	51.42	14.41	2.09	.905	.147	.506	9.86	1.26	11.12	+ 1.8	+ .2	30.5	.253	1.094	.....
2355	83.39	16.61	10.59	1.05	.565	.059	.388	8.02	None.	8.02	− .2	.0	31.0	.186	6.693	.....
Orange:																
Kona	72.13	27.87	12.15	2.57	.453	.882	.681	2.09	3.81	5.90	+ 3.5	−1.4	28.3	.387	.575	.....
Waialua	70.50	29.50	9.56	2.60	.505	1.058	.819	4.25	2.99	7.24	+ 3.2	− .6	31.4	.....	3.66	.....
Japanese	71.26	28.74	11.20	2.16	.353	.749	.831	3.82	2.83	6.65	+ 3.0	− .6	30.6	.448	.479	.....
Chinese	68.75	31.25	10.81	3.01	.522	3.758	.....	.....	.....	.....	.....	.....	.....	.303	.777	.....
Shaddock	42.39	57.61	11.53	6.14	.486	.196	1.175	.86	7.26	8.12	+ 7.6	−1.6	31.8	.140	1.977	.....
Limes	49.17	50.83	11.75	.11	.352	6.830	.675	1.50	None.	1.50	− 0.4	− .2	31.5	3.561	.065	.....
Lemons (rough)	33.14	66.86	6.44	.30	.232	3.371	.356	1.53	.47	2.00	+ 2.2	+1.6	32.3	1.49	.084	.....
Guava (*Psidium guajava*):																
Common	84.69	15.31	17.78	7.27	.531	.363	1.125	6.61	.77	7.38	− 1.8	−2.8	30.2	.524	4.445	.....
White	87.76	12.24	18.75	7.73	.676	.451	1.525	5.73	2.53	8.26	− .2	−3.4	32.3	.412	5.105	.....
Trinidad	86.62	13.38	15.43	8.99	.651	.261	1.506	5.79	.55	6.34	− 2.5	−3.2	31.0	.353	4.425	.....
Guava (*Psidium cattleianum*):																
Chinese strawberry	98.01	1.99	20.08	7.36	.635	.696	.....	3.64	6.37	10.01	+ 4.70	−3.4	31.0	.418	3.868	.....
Common strawberry	98.60	1.40	18.27	9.97	.743	1.171	1.038	2.41	2.05	4.46	+ 1.8	− .8	31.7	.554	6.146	.....
Common strawberry	81.16	18.84	23.75	14.47	.755	.715	1.838	2.32	3.31	5.63	+ 2.4	−1.8	32.0	.790	9.378	.....
Fig: (*Ficus carica*):																
——— ———	80.39	19.61	16.96	2.85	.475	.127	.988	12.98	None.	12.98	− 1.8	−1.6	31.6	.368	1.275	.....
2384: 1	81.96	18.04	17.72	2.09	.548	.137	1.250	12.75	0.39	13.14	− 1.5	−2.0	33.2	.210	1.149	.....
Tantalus	78.34	21.66	10.27	2.18	.454	.167	1.963	6.28	None.	6.28	− .5	− .4	30.5	.261	1.073	.....
Pineapple (*Ananas sativus*) [2]	.....	.....	.....	.....	.....	.66	.375	3.92	6.78	10.70	+ 5.0	−3.6	31.7	.....	.....	.....
Grape (*Vitis labrusca*):																
Isabella	56.25	43.75	15.73	6.67	.205	.490	.394	16.19	None.	16.19	− 5.0	−4.8	28.7	.238	.289	.....
Sweet sop (*Anona squamosa*)	53.47	46.53	21.33	4.07	.844	.215	2.038	16.51	None.	16.51	− 3.4	−3.6	31.7	.547	1.632	.....
Do	55.73	44.27	24.82	5.48	.673	.127	1.531	15.27	2.88	18.15	− .7	−4.4	27.7	.548	1.225	.....
Cherimoya (*Anona cherimola*)	84.23	15.77	33.81	9.86	.669	.064	1.838	15.34	3.07	18.41	+ .3	−3.6	31.4	.145	4.293	.....
Star apple (*Chrysophyllum cainito*)	86.90	13.10	11.47	5.46	.392	.127	2.338	2.67	1.73	4.40	+ 1.6	− .6	31.5	1.385	.857	.....
Mountain apple (*Eugenia malaccensis*)	73.87	26.13	8.61	.....	.137	.068	.213	6.88	None.	6.88	− 2.1	−2.1	29.0	.035	.562	.....
Rose apple (*Eugenia jambos*)	62.94	37.06	15.85	3.70	.299	.039	.794	11.26	.47	11.73	− 1.2	−1.8	30.3	.189	.982	.....
Java plum (*Eugenia jambolana*)	57.50	42.50	15.63	3.54	.287	.838	.619	12.99	None.	12.99	− 3.0	−2.8	32.7	.524	.164	.....
Surinam cherry (*Eugenia michelli*)	84.38	15.62	9.30	1.93	.342	1.440	1.019	4.68	1.38	6.06	− 1.0	−2.8	25.0	.664	.343	.....
Loquat (*Eriobotrya japonica*)	60.00	40.00	10.02	2.71	.385	.666	.413	1.79	2.09	3.88	+ .5	−2.2	27.5	.500	.653	.....
Roselle (*Hibiscus sabdariffa*):																
Calyx	55.43	44.57	11.58	5.03	.651	2.263	1.231	.20	None.	.20	+ .4	+ .4	29.0	.819	1.454	1.57
Seed pods	.....	.....	23.73	16.91	1.078	.637	4.000	.27	1.09	1.36	+ 1.0	− .4	29.5	1.152	6.621	4.18
Ceriman (*Monstera deliciosa*)	73.88	26.12	22.12	2.12	.851	.353	1.181	16.19	None.	16.19	− 4.4	−4.6	33.5	.205	.569	.....
Natal plum (*Carissa grandiflora*)	78.12	21.88	21.55	4.29	.437	1.196	.563	12.00	None.	12.00	− 5.6	−5.2	32.3	1.03	.918	.....
Carambola (*Averrhoa carambola*):																
Sweet	100.00	None.	8.22	3.13	.421	.784	.719	3.40	None.	3.40	− .7	− .7	31.3	.755	1.237	.....
Sour	100.00	None.	8.69	2.84	.408	.309	.....	5.25	.16	5.41	− .6	− .8	29.5	.314	.992	.....
Tamarind (*Tamarindus indica*)	48.28	51.72	69.51	17.68	1.823	11.329	3.431	18.74	2.58	21.32	+ 3.3	.0	31.2	.851	5.615	.....
Pomegranate (*Punica granatum*):																
Whole fruit	56.06	43.94	26.33	10.14	.591	.122	1.488	12.21	None.	12.21	− 3.2	−3.2	30.2	.477	5.297	.....
Pulp	46.88	53.12	17.52	1.98	.735	.137	.525	15.00	1.07	16.07	− 2.6	−4.0	30.0	.304	.329	.....
Poha (*Physalis peruviana*)	100.00	None.	17.86	6.78	.733	1.009	.....	2.67	5.97	8.64	+ 6.4	−1.2	30.7	.331	4.730	.....
Do	100 00	None.	17.76	7.09	.829	1.214	2.006	2.25	5.49	7.74	+ 6.6	− .4	30.5	.298	3.828	.....

[1] Determined by copper reduction method.

[2] Hawaii Sta. Rpt. 1910, p. 47.

Issued June 23, 1916.

HAWAII AGRICULTURAL EXPERIMENT STATION,
J. M. WESTGATE, Agronomist in Charge.

REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION.

1915.

UNDER THE SUPERVISION OF
STATES RELATIONS SERVICE,
Office of Experiment Stations,
U. S. DEPARTMENT OF AGRICULTURE.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1916.

HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU.

[Under the supervision of A. C. TRUE, Director of the States Relations Service, United States Department of Agriculture.]

E. W. ALLEN, *Chief of Office of Experiment Stations.*

WALTER H. EVANS, *Chief of Division of Insular Stations, Office of Experiment Stations.*

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A. T. LONGLEY, *Executive Assistant.*

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[1] Appointed July 25, 1915, to succeed Wm. T. McGeorge, transferred to U. S. Department of Agriculture, Bureau of Chemistry.
[2] Resigned June 30, 1915.
[3] Appointed July 6, 1915, to succeed F. A. Clowes, resigned.

LETTER OF TRANSMITTAL.

HAWAII AGRICULTURAL EXPERIMENT STATION,
Honolulu, Hawaii, September 14, 1915.

SIR: I have the honor to transmit herewith and to recommend for publication a report of the Hawaii Agricultural Experiment Station, 1915.

Respectfully,

J. M. WESTGATE,
Agronomist in Charge.

Dr. A. C. TRUE,
Director States Relations Service,
U. S. Department of Agriculture, Washington, D. C.

Publication recommended.
A. C. TRUE, *Director.*

Publication authorized.
D. F. HOUSTON,
Secretary of Agriculture.

when green has no store of carbohydrates upon which to draw, it must obtain its sugars by translocation from the trunk of the trees.

In comparing the banana with the papaya it is noted that the banana contains higher percentages of total solids, carbohydrates, protein, acid, and ash, and is altogether a more substantial fruit. It is of interest to note that the total solids decrease in the banana during the ripening process but increase considerably in the papaya. The banana contains large amounts of starch and other carbohydrates when green. It may, therefore, be separated from the tree at that time and on ripening still contain a normal amount of sugar due to the hydrolysis of its starch. In the papaya no such store of food is held.

It is also interesting to note that the banana contains sucrose and reducing sugars. The papaya, on the other hand, has practically no sucrose but considerable reducing sugars. The fat content is more constant in the papaya during ripening and the fiber is higher than in the banana.

In both fruits the acid-sugar ratio is low.

Some of the changes in the composition of the Chinese banana and of the papaya during the ripening process are shown in the accompanying table.

Composition of the Chinese banana and the papaya at different stages of ripeness.

Stage of ripeness.	Edible portion.	Waste.	Total solids.	Insoluble solids.	Ash.	Acids as H_2SO_4.	Protein.	Sugars.			Polarization.			Starch by diastase method.	Hydrolyzable carbohydrates other than starch or sugar.	Fat.	Fiber.	Undetermined matter.
								Reducing.	Sucrose.	Total.	Direct.	Invert.	Temperature.					
Chinese banana.																		
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*° V.*	*° V.*	*° C.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Green (a)	57.48	42.52	23.51	16.25	0.871	0.196	2.013	0.15	0.31	0.46	+ 1.6	+1.2	25.3	17.38	1.16	0.025	0.276	1.13
Green (b)	.....	.....	28.51	25.25	.891	.114	1.275	.10	.53	.63	+ .6	− .1	25.3	19.97	1.23	.055	.370	3.97
Half ripe (a)	63.64	36.36	21.98	10.78	.948	.343	1.838	4.93	4.17	9.10	+ 4.2	−1.2	26.2	5.02	2.28	.151	.335	1.96
Half ripe (b)	57.76	42.24	27.56	14.90	.921	.320	1.331	3.53	7.31	10.84	+ 6.8	−2.6	28.3	7.93	1.64	.091	.314	4.17
Ripe (a)	70.00	30.00	21.28	2.45	.955	.245	1.788	8.18	8.48	16.66	+ 7.9	−3.2	23.7	None.	None.	.180	.253	1.20
Ripe (b)	67.00	33.00	24.47	2.66	.883	.156	1.119	7.41	11.26	18.67	+10.4	−4.2	25.6	.43	.49	.257	.309	2.16
Papaya.																		
5 months before ripeness	71.00	29.00	6.48	3.28	.621	.065	.800	2.15	.23	2.38	+ 1.5	+1.2	30.7	.....	.26	.205	.873	1.28
5–6 weeks before ripeness	80.97	19.03	6.13	2.38	.451	.045	.381	2.88	None.	2.88	+ 1.0	+1.2	28.0	.....	.49	.186	.602	1.09
4 weeks before ripeness	81.24	18.76	6.13	2.31	.427	.045	.388	2.81	.23	3.04	+ .7	+ .4	27.8	.....	.01	.188	.692	1.34
3 weeks before ripeness	81.13	18.87	6.26	2.46	.471	.026	.306	2.93	None.	2.93	+ .7	+ .8	26.7	.....	.45	.208	.716	1.1
2 weeks before ripeness	78.73	21.27	6.45	2.49	.425	.044	.306	4.13	.47	4.60	+ .6	.0	31.0	.....	.00	.261	.581	.23
8 days before ripeness	84.65	15.35	8.92	2.37	.508	.033	.356	5.99	None.	5.99	− .2	− .2	30.0	.....	.12	.163	.654	1.10
1 day before ripeness	84.99	15.01	10.68	1.18	.514	.059	.463	7.82	.47	8.29	− .6	−1.2	27.5	.....	.....	.168	.592	.65
Entirely ripe	83.39	16.61	10.59	1.05	.565	.059	.388	8.02	None.	8.02	− .2	.0	31.0	.....	.00	.186	.693	.68

Issued June 23, 1916.

HAWAII AGRICULTURAL EXPERIMENT STATION,
J. M. WESTGATE, Agronomist in Charge.

REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION.

1915.

UNDER THE SUPERVISION OF
STATES RELATIONS SERVICE,
Office of Experiment Stations,
U. S. DEPARTMENT OF AGRICULTURE.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1916.

HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU.

[Under the supervision of A. C. TRUE, Director of the States Relations Service, United States Department of Agriculture.]

E. W. ALLEN, *Chief of Office of Experiment Stations.*

WALTER H. EVANS, *Chief of Division of Insular Stations, Office of Experiment Stations.*

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J. EDGAR HIGGINS, *Horticulturist.*
M. O. JOHNSON,[1] *Chemist.*
D. T. FULLAWAY,[2] *Entomologist.*
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ALICE R. THOMPSON, *Assistant Chemist.*
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[1] Appointed July 25, 1915, to succeed Wm. T. McGeorge, transferred to U. S. Department of Agriculture, Bureau of Chemistry.
[2] Resigned June 30, 1915.
[3] Appointed July 6, 1915, to succeed F. A. Clowes, resigned.

LETTER OF TRANSMITTAL.

HAWAII AGRICULTURAL EXPERIMENT STATION,
Honolulu, Hawaii, September 14, 1915.

SIR: I have the honor to transmit herewith and to recommend for publication a report of the Hawaii Agricultural Experiment Station, 1915.

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REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION, 1915.

SUMMARY OF INVESTIGATIONS.

By J. M. Westgate, *Agronomist in Charge.*

INTRODUCTION.

The station has continued as in the past to aid in the development of diversified agricultural industries in the islands. There are a number of crops that have been found agriculturally possible which at present are not able to compete economically with sugar, and the station has continued its experimental and extension work to place some of these on a profitable basis. It is felt that the most stable prosperity is that which is based upon a number of lines of industry rather than upon a single crop. To this end the station is collecting data as to the agricultural possibilities of different crops on the different soils of the various islands. As rapidly as possible the cultural requirements of these various crops in relation to soils, altitudes, and moisture supply are being worked out.

BUILDINGS AND GROUNDS.

During the year only minor repairs and additions were made in connection with the station buildings. The roofs of three of the buildings were treated with roof-preserving paint in order to prolong the life of the shingles. The foundations of the same buildings were also repaired where decay and insect pests had weakened or destroyed the timbers. It was found necessary to rebuild one of the large water tanks holding a reserve water supply of 60,000 gallons.

The Marine-Hospital Service tract of land adjoining the station grounds was resurveyed and laid out in plats for the department of agronomy. The survey indicated that there were about 3 acres available for cultivated crops. This ground was replowed and planted to corn, potatoes, and various green-manure crops.

Owing to the uneveness of the soil as well as to the high cost of water for irrigating, especially for rice and taro, the lease of the Wyllie Street tract was terminated at the end of the year. Arrangements have been made with private rice and taro growers for cooperative experiments along the same lines as those carried out on this tract, and at considerably less expense to the station.

Preliminary arrangements were made with the officers in charge of the Army reservations for the lease of a tract of 10 acres of land for the purpose of determining the possibility of forage production for the Army horses. The rainfall is somewhat limited, but it is expected that proper methods of tillage and spacing will make possible economical yields of certain species of forage grasses.

CHANGES IN THE STATION STAFF.

During the year a considerable number of changes were made in the scientific staff of the station. On January 1, 1915, E. V. Wilcox, special agent in charge, was transferred to Washington, D. C., and was succeeded by J. M. Westgate, who was transferred from the Office of Forage Crop Investigations, United States Department of Agriculture. D. T. Fullaway, entomologist, returned from his year's furlough on June 1, 1915, but resigned June 30, 1915, to accept a position with the Territorial Board of Agriculture and Forestry in connection with the search for parasites of the melon fly (*Dacus cucurbitæ*). W. P. Kelley, chemist, resigned October 27, 1914, to become professor of agricultural chemistry in the Graduate School of Tropical Agriculture and Citrus Experiment Station at Riverside, Cal. He was succeeded by Wm. T. McGeorge, formerly assistant chemist at this station. Mr. McGeorge in turn left the station June 30, 1915, on a transfer to the Bureau of Chemistry, United States Department of Agriculture. Mr. McGeorge's transfer, however, did not become effective until July 8, 1915. F. A. Clowes, superintendent of Hawaii substations, resigned June 30, 1915, to take charge of the agricultural department of the Lahainaluna Industrial School, where he will be retained as a collaborator of this station in order that he may attend to the work done in cooperation with that institution. F. G. Krauss was appointed superintendent of extension work beginning November 1, 1914. Mr. Krauss was formerly agronomist of this station, but had resigned to become professor of agronomy at the College of Hawaii, which position he was filling at the time he was appointed to take charge of the extension work of this station. J. de C. Jerves was appointed collaborator January 1, 1915, at Homestead, Kauai; John E. Gamalielson, April 1, 1915, at Hilo, Hawaii; and John McCoy, May 1, 1915, at Kamuela, Hawaii, to assist in the extension work among the small farmers of those sections. George Copp was appointed collaborator January 1, 1915, at Waiakoa, Maui, but resigned June 30, 1915.

TERRITORIAL MARKETING DIVISION.

The Territorial legislature at its 1913 session appropriated funds for the maintenance of a marketing division for Hawaiian-grown

products and the station was given supervision of the project. Not a little of the satisfactory results of the work of the marketing division has been due to the loyal support of the local newspapers and other agencies and individuals interested in the upbuilding of the lesser agricultural industries of the islands.

During the year the division has made a large increase in the amount of produce handled, the sales amounting to $69,182.50 against $26,095.10 for the preceding year. The consignments which have been received have generally been in better condition than formerly, but there is yet much to be done in educating the shipper to pick, grade, and pack his products properly.

Practically all Hawaiian agricultural products except sugar have been handled by the division, most of them successfully. The onion crop harvested this year met a very poor market due to the large hold-over supply of 1914 mainland onions. Prices on the mainland were so low that it did not pay to ship our early Bermuda onions, but fresh pineapples, bananas, Maui beans, and a small shipment of copra have brought good returns.

The division has continued to publish and distribute to the producers of the Territory the Weekly Market Quotation Sheet. This sheet gives the current wholesale quotations on island products and keeps the farmer in touch with the condition of the market. This sheet is also published by most of the papers of the Territory. Growers generally do not realize the importance of keeping the division posted as to the amount of produce they have to send to market and when it may be expected to arrive, but there has been considerable improvement in the past few months. It is safe to say that the producer has received better prices since the division was established than ever before, whether he marketed his produce through the division or elsewhere.

Up to the present time the division has been seriously handicapped due to the poor facilities for handling such a large assortment of products as has been sent in for sale. With the appropriation of $14,400 for a new building and equipment made by the last legislature and an appropriation of $1,000 a month for the ensuing biennium for general expenses, most of the present difficulties should be overcome. The last legislature also filled a pressing need when it appropriated $7,500 to be used as a revolving fund for buying seed and crates to be resold to the farmers and for making advances on consignments. This fund has made it possible for the division to supply the growers with crates in which to ship their pineapples to the mainland without requiring payment for the crates until returns are received for the fruit.

Due to the apparent overproduction of pineapples in Hawaii and the prospect of a large portion of the 1915 crop rotting in the field

for want of a purchaser at a price less than half the cost of production, the division opened a branch office in San Francisco to sell fresh pineapples and such other products as find a better market on the mainland than at home.

HORTICULTURAL INVESTIGATIONS.

Horticultural investigations have continued along lines similar to those of recent years.

The litchi (*Litchi chinensis*) has received considerable attention. The excellence of this fruit, its high price, and its apparent adaptability to Hawaii have commended it for further investigations. The high price of the fruit is due to the limited supply and its popularity, not only among the Chinese, who are most familiar with this fruit, but also among all classes of the population. One of the reasons for the limited supply lies in the slowness of the methods of propagation in vogue, while another cause may be found in the great tardiness of seedling trees in coming into bearing. Experiments are being conducted to facilitate more rapid propagation by asexual means in the hope of overcoming both of these difficulties. Considerable progress has been made along these lines.

Attention has also been given to the preservation of the fruit for short periods in refrigeration, and also to various methods of transporting the seeds, which, under ordinary conditions, retain their viability only a few days. No deterioration in appearance or flavor of the fruit has been noted during refrigeration for the short periods which were tried. Other experiments along these lines are necessary. It was found possible to ship the seeds by mail in sphagnum moss, seeds having been sent by this means from Honolulu to Florida, where they are reported to have arrived in excellent condition.

In the mango investigations some studies have been made of the flowers and of the technique of cross-pollination. Bark grafting has been applied to the mango with considerable success, thus adding one more means for the top-working of established mango trees with choice varieties. Some of the new varieties of mango are not only superior to the common strains, but are more resistant to the Mediterranean fruit fly.

Some observations have been made of the keeping qualities of the Macdonald variety of avocado. Fruits were kept in the horticultural laboratory for 16 days without any refrigeration, and at the end of this time were in a perfect state of preservation. Bark grafting was tested on the avocado, but proved not to be so successful as scion budding, which consists in the inserting of the scion in a T-shaped incision in the bark of a mature branch.

Further pollinations of the papaya have been made, and lines of close-breeding as well as cross-breeding have been started.

A number of experiments have been made in the cross-pollination of two species of Aleurites, *A. moluccana*, the ordinary kukui of Hawaii, and *A. fordii*, known as the Chinese wood-oil tree. There are 120 fruits set, which are the result of these crosses, unless it may prove that some of them represent parthenocarpic or parthenogenetic developments.

The distribution of seeds and plants has been continued, chiefly with the varieties that have been under investigation, such as hibiscus, papaya, citrus, mango, and avocado.

ENTOMOLOGICAL INVESTIGATIONS.

On account of the absence of the entomologist for 11 months of the year, but little station work along entomological lines was accomplished. The insect collection was maintained, however, and a number of requests for assistance in combating insect pests were complied with either by personal visits or by advice as to the best methods of procedure. It had been anticipated that the entomologist while on furlough to the Territorial Board of Agriculture and Forestry, would be able to locate effective parasites for the pink bollworm of the cotton plant, but it was deemed inexpedient to assign him to this particular problem. Studies concerning the life history of the pink bollworm of cotton were made by August Busck, of the Bureau of Entomology, United States Department of Agriculture. Mr. Busck was given use of the insectary and entomological laboratory to facilitate the prosecution of his investigations.

CHEMICAL INVESTIGATIONS.

The relative value of the different forms of phosphate fertilizers has been determined in a series of pot experiments with three types of Hawaiian soils. The crops used were Japanese millet, cowpeas, buckwheat, radishes, and turnips. The results indicate that bone meal or other difficultly soluble phosphates are of little value as fertilizers in most parts of the Hawaiian Islands, since the soil already contains a large quantity of insoluble phosphate. For the best returns the phosphoric acid should be used in the form of soluble phosphate and in light applications at frequent intervals. The insoluble phosphates are of little value except in the wet districts. In soils high in iron and alumina, lime has in the past been added with applications of soluble phosphates in order to delay the formation of iron and aluminum phosphates. It has been found, however, that plants fertilized with iron and aluminum phosphates have made very satisfactory growth.

Organic phosphorus in rice was found to be present in the form of phytin. Since the phytin occurs in unpolished rice and rice bran, but not in the polished rice, it is evident that the phytin is normally present only in the outer layers of the rice grain.

This station has been a persistent advocate of the use of legumes for green manuring for many years. Pot cultures have been made with 32 species of legumes. In one series of pots the entire plant has been turned under in order that the humus value and amount of nitrogen added may be determined. In the second series the nitrogen fixed by the plants has been determined. It was found that the nitrates in pots where legumes had been grown were much lower than in the check pot, but after removing the plant and allowing the pot to stand in the open the amount of nitrates soon equaled that in the check pots. Lime was found to be necessary for the best growth of the legumes.

Arsenite of soda has had quite an extensive use as a weed destroyer. In soil which had been sprayed with this chemical the arsenic was found to have accumulated in the top 4 inches of soil. The use of such sprays in excessive amounts should therefore be avoided.

The peculiar character of Hawaiian soils makes necessary some modifications of the ordinary methods of soil analysis. The experience in soil analysis on the part of the various chemists employed at this station has been summarized, and a modified method of analysis has been prepared and is given in the body of this report.

A bulletin of the station entitled "The Soils of the Hawaiian Islands"[1] gives the results of six years' work on Hawaiian soils, together with the practical application of the results obtained. Successful soil management requires deep plowing, followed by frequent shallow cultivations. Because of the heavy clay character of the soils and consequent danger of "puddling," the maintenance of the humus content by rotation of crops and green manuring is essential for the best results. Proper drainage is also important. In general, both nitrogen and phosphoric acid give good results as fertilizers. Soluble phosphates are recommended except in wet districts. Where there is a heavy rainfall the insoluble phosphates are best. Under similar conditions organic and ammoniacal nitrogen are better than the nitrate.

AGRONOMIC INVESTIGATIONS.

The principal crops experimented with during the year were rice, taro, corn, potatoes, cotton, millet, as well as various forage grasses and legumes. In a liming and fertilizer test the yield of shelled

[1] Hawaii Sta. Bul. 40 (1915).

corn was greatest on the plat receiving lime only, the same having been applied at the rate of 1,100 pounds per acre.

In an experiment to determine the effect of soil aeration on yields of rice it was found in the first experiment that 308 pounds more per acre was obtained from the aerated than from the nonaerated plat. The second test showed 680 pounds per acre in favor of aeration.

In a preliminary test for determining the effect of aeration on yields of taro the taro itself showed a slightly increased yield, while the "hulis" (offsets) showed a considerable increase on the aerated plat.

In a spraying test with Bordeaux mixture and lime sulphur for potato fungi on Early Rose potatoes the plat sprayed with Bordeaux produced at the rate of 30.2 bushels, as compared with 25.9 bushels for the lime-sulphur spray and 15 bushels per acre for the check.

In the tests of legumes for green manuring jack beans and velvet beans are among the most promising.

In an alfalfa yield test the ordinary alfalfas were found to outyield both the Peruvian and Turkestan varieties.

The sorghums constitute a very promising class of green forage crops, some averaging as high as 15 tons per acre, with the cutting 90 to 100 days apart.

Of the forage grasses Sudan grass is easily the most promising for general use throughout the islands. The fondness of the birds for seed of this grass makes the problem of seed production a difficult one. The station plats are protected with bird-proof nets.

Interesting results were obtained from Japanese millet. Yields as high as 12 tons of green forage, 3 tons of roughage, and 30 bushels of seed per acre have been obtained. Plantings of this crop are most satisfactory when made in November and December and harvested in January and February, the time of year when sorghums are not making rapid growth.

Numerous distributions of seed from all the more promising grasses and leguminous forage crops, as well as other field crops, have been made to farmers having facilities for making tests and increasing the available seed supply of the particular species in question.

AGRICULTURAL EXTENSION.

The extension division was definitely organized in November, 1914, although considerable extension work had been in progress before that date. The work centers in part in the substations referred to elsewhere in this report and in part in the various extension activities, such as demonstration farm work, trips to various stations on

the part of extension workers, assistance at agricultural fairs, fostering of boys' and girls' agricultural clubs, together with field demonstrations of improved means of crop production on private farms under the general supervision of the extension agents. It is felt that a great deal of good has been accomplished as a result of the voluminous correspondence with persons who have written to the station asking for advice and information concerning their more pressing agricultural problems. One of the most serious problems in connection with the extension work is that of providing for the large amount of travel that appears to be necessary if the agents are to keep in touch with the various individuals they should reach. Travel by water to a number of places is possible only by boats that make the call at rather infrequent intervals. On land the distances between the different sections are often such as to make automobile service essential in the interests of time economy. The commercial charges are such as to make it impossible to use such service except in cases of extreme emergency. It is true that a great many individuals have their own automobiles and willingly place them at the disposal of the extension agents for the visit to their places. Those who most need the services of the extension division, however, are seldom in a position to provide transportation of any kind.

SUBSTATIONS.

Owing to the withdrawal of Territorial funds, it was found necessary to abandon the various substations with the exception of that at Glenwood, which was continued on a greatly decreased allotment, a part of which came from private subscriptions. The banana work at Hilo, however, was continued under the supervision of the superintendent of the Glenwood substation. The extension funds of the station have made possible the employment of several collaborators who devote portions of their own farms to demonstration work and use the results obtained as a basis in part for extension work among the farmers they are able to reach. Work of this kind is under way at Haiku, Maui; at Hilo, Hawaii; at Kamuela, Hawaii; and at Kalaheo homestead, Kauai. At Hilo the collaborator is chiefly concerned with the development of improved methods of butter making in order that the product may compete more successfully with butter imported from the mainland. At Kamuela a typical homestead is being conducted by the collaborator at that place. He is making a number of trials of various crops to determine which are economically practicable under the local conditions. For instance, it is found that, while a considerable number of fresh green vegetables can be produced, it does not seem profitable to ship

them to Honolulu, owing to the long haul to the wharf, the high freight rate, and the rough treatment often accorded such shipments because of the necessity of transferring the shipments from small boats to the steamers, which are unable to reach the wharf. It therefore seems advisable for homesteaders in such sections to raise pigs and poultry and such crops as can be marketed in a dry condition and in quantity. At Kalaheo homestead the collaborator has given considerable attention to the extension of the poultry industry throughout his immediate section. He has also become interested in the possibilities of starch production from cassava, and a number of his neighbors are planting considerable acreages. At the present time the starch is selling for 7 cents a pound. At Haiku both extension work and demonstration work are under way on a comparatively large scale, and a separate report of the work of this station, as well as of that at Glenwood, appears in this report.

This station maintains what is essentially a substation on the slopes of Mount Tantalus at an elevation of about 1,000 feet. The station reservation includes all the land between the Tantalus substation and the station plats at the lower end of the tract, but most of the intervening land is uncleared and in this condition is not suitable for experimental work. At the upper station there are under test and observation numerous species of plants which do not thrive at lower altitudes. The principal crops under test are bananas, coffee, rubber, avocado, Chinese wood-oil nuts, Macadamia nuts, citrus trees, and roselle.

GLENWOOD SUBSTATION.

The reduction of the Territorial allotment for the work of the Glenwood substation materially handicapped the work of the station during the entire year, only the bare maintenance and a few other essential expenditures being possible. In spite of this handicap, which necessitated material curtailments in its activities, much good has resulted from the continued operation of the station. The dairy herds of the entire section have been improved by the utilization of the herd bull, while the sale of eggs for hatching from the station poultry flocks has materially improved many of the flocks throughout the islands. The introduction of such grasses as *Paspalum dilatatum* and the demonstration of the best methods of utilizing the native honohono have been of much assistance to the small farmer, who is largely dependent upon his herd of live stock for a livelihood. In addition to the actual work of the substation itself, the superintendent has taken an active interest in a large number of agricultural activities concerning which his advice and assistance were sought and apparently much appreciated.

NEEDS OF THE STATION.

There are several pressing needs of the station to which it is desired to call attention. At the station itself the services of a plant pathologist are needed. There are a number of plant diseases which manifestly lessen the production of several of the island crops which would otherwise be much more profitable. Among these may be mentioned potato blight, late blight of celery, a banana disease of somewhat obscure nature, a root rot of taro, and several other diseases which are not conspicuous simply because the crops which they attack are not at present being grown to any considerable extent on account of economic conditions prevailing in the islands. It is highly desirable that as complete information as possible be obtained concerning the best methods of controlling such plant diseases as now stand in the way of extensive production of the crops affected.

Hawaii presents, within limited areas, a greater diversity of climatic and soil conditions than can be found in an area of the same size in any part of the mainland of the United States. Within 3 or 4 miles the rainfall may vary from a few inches to 10 or 12 feet per year. The changes in altitude on the rapidly ascending mountain slopes cause changes in temperature varying from strictly tropical to that of the region of frost and snow. This great diversity gives rise to regional limitations of adaptability. Pineapples, for example, prosper at certain altitudes where there is sufficient rainfall. Coffee likewise flourishes at certain altitudes and under certain conditions of soil and rainfall, but elsewhere is a failure. Hence it becomes necessary that many of the problems pertaining to crop production be worked out in the localities typical for each crop. It is important that there should now be a pineapple substation where the problems of this industry, second only to sugar cane in value, might be worked out.

As another particular instance it may be mentioned that at Schofield Barracks there is a great need of forage for the Cavalry horses and work mules. At present hay has to be brought from the mainland at large expense for freight alone. There is available on the reservation probably sufficient ground to grow all the roughage required when once the proper varieties and cultural requirements have been determined. It has therefore been recommended that a local substation be established on the tract in question where the practicability of growing suitable grasses or other forage can be definitely determined.

It is therefore recommended that as fast as funds will permit there be established substations in the sections where crop problems are most pressing, and where the potential importance of the crops in question is sufficient to justify such an expenditure.

PUBLICATIONS.

During the year the following publications were issued by the station:

Annual Report for 1914.
Bulletin 35, Absorption of Fertilizer Salts by Hawaiian Soils.
Bulletin 36, Grasses and Forage Plants of Hawaii.
Bulletin 37, Ammonification and Nitrification in Hawaiian Soils.
Bulletin 38, Effect of Fertilizers on the Physical Properties of Hawaiian Soils.
Press Bulletin 47, Cold Storage for Tropical Fruits.
Press Bulletin 48, Suppression of Weeds Among Pineapples by Arsenite of Soda Spray.
Press Bulletin 49, A Cheap and Effective Home-made Plank Drag.
Press Bulletin 50, The Effect of Arsenite of Soda on the Soil.

REPORT OF THE HORTICULTURAL DEPARTMENT.

By J. Edgar Higgins.

The work of the horticultural department has been continued along lines similar to those of recent years. During the first part of the year the horticulturist was absent from the office, having reported for duty in Porto Rico at the close of a year's leave of absence. The latter part of June of the last fiscal year was spent in investigations of the fruit industries of Porto Rico, and the early part of the present fiscal year in travel in Cuba and Florida. The purposes of this travel were to observe horticultural conditions and progress in the countries visited with a view to the improvement of horticultural practices in Hawaii. The results of these investigations have been prepared for presentation in a separate report (see p. 58).

THE EXTENSION OF THE LITCHI.

The litchi, *Litchi chinensis* (*Nephelium litchi*), is now attracting considerable attention, not only in Hawaii (see Pl. I, fig. 1), but also in Florida and southern California. It appears probable that this fruit tree is adapted to a wider range of conditions than has been supposed. The excellence of the fruit and its very high price in Honolulu (60 to 75 cents a pound), due to the limited supply, makes it worthy of more attention. Considerable data have been accumulated during the year on methods of propagation, preservation of seeds, fruiting age, cultural methods, etc., which are being brought together in a separate paper. This station is cooperating in experiments in Florida and California with this species. A large number of seeds has been shipped to Florida in the pursuit of this work, and also as an experiment in transporting these short-lived seeds. About 50 pounds of fruit was shipped to the Office of Foreign Seed and Plant Introduction, in Washington, D. C., as a further means of testing the possibilities of the shipment of seeds and fruits. The shipment went in refrigeration as far as San Francisco and thence by ordinary express, icing being impossible with so small a quantity. The fruits are reported to have arrived in good condition.

On July 5 another small lot of fruit was placed in the fruit room of the United States Army transport *Thomas* at Honolulu en route for San Francisco. These were removed from refrigeration by the writer before arrival in San Francisco. They were in perfect pres-

ervation, apparently having lost nothing in flavor and appearance. Part of the seed was sent by mail in moist sphagnum moss to Washington, D. C., and part was distributed in localities of California, where it is hoped this species may succeed. All of this seed germinated well, demonstrating that it was not injured by refrigeration, and, further, that this is one of the means by which litchi seeds may be transported where refrigeration for fruit is available.

THE MANGO.

A number of interesting facts have been observed in the mango studies. Some preliminary studies have been made on the flowers of certain varieties and on methods of pollination. In the Alphonse variety, for example, it was found that a very large proportion of the flowers of the lower (inner) portion of the cluster was staminate. These staminate flowers have but one fertile stamen and four staminodes. They are unisexual by the abortion of the pistil, which sometimes may be detected in its aborted condition. These staminate flowers, while most abundant in the lower part of the lateral clusters, are also found throughout the entire cluster except near the outermost end of the central axis. The hermaphrodite or perfect flowers are found in all parts of the cluster, but chiefly near the termination of the lateral branches and of the central axis. At the base of the lateral clusters there are very few. These hermaphrodite flowers have but one stamen and one pistil, with four staminodes. The pistil is without any marked enlargement at the stigma.

The pollen of all the varieties of mango studied was found to be very small and almost colorless. In the few cross-pollinations which were made the ruptured anthers were brought into immediate contact with the flower being used as the female parent. This appeared to be a more practical means than any attempt to gather minute pollen grains and apply them with a brush.

PREMATURE FLOWERING.

Several mango seedlings less than 9 months old which had been grafted by inarching were found to be producing flower clusters above the point of union. In most cases the scion also was flowering, but in one case only the seedling stock. The mango tree ordinarily does not flower until it is from 5 to 6 years old, and the flowering of young seedlings less than a year old is quite beyond any observations that have been made here, and, so far as the writer is aware, no such cases have been previously recorded. Of 27 seedlings grafted to the Pirie, 4 produced flower clusters on the scions only, and 5 produced flowers on both seedlings and scions; of 5 grafted to the variety Brindabani, 1 produced flowers on the scion and on the seedling

stock, and 1 produced flowers on the seedling stock only, with none on the scion. That is to say, 18 per cent of the plants grafted to Pirie and 20 per cent of those grafted to Brindabani formed flowers on both scions and stock. There is, of course, nothing remarkable in the production of flowers on the scions. It is very common to find scions producing flowers from flower buds which have been matured on the tree before the removal of the scion, but flowers on seedling mango stocks less than 1 year old are worthy of note.

No cause can be ascribed for these phenomena except the grafting. It is true that the seedlings had been cut back slightly to induce growth in the scion, but this injury to the top of seedlings frequently occurs. Possibly the unusual results may be accounted for by the influence of the scion upon the stock, and it will be noted that in all cases save one the scions flowered as well as the stocks. In this one exception, the scion showed the scar of a flower cluster of the last season at its terminus. The mere mechanical injury brought about by grafting and the constriction resulting from the tightening of the raffia bands should also be taken into consideration. Plate I, figure 2, shows some of the trees referred to bearing their flowers.

BUD MUTATION.

Instances of bud mutation have not been commonly reported in the case of the mango. An instance apparently illustrating this phenomenon has recently received attention. Several trees grown from seed of the variety locally known as No. 9 have all produced fruits of the general type. A single branch of one of these trees, however, produced a pink fruit (the No. 9 is green), rather smaller in size than the regular type, but otherwise resembling the variety from which it was grown.

BARK GRAFTING.

The bark grafting of the mango, which has been successfully applied by the Porto Rico Experiment Station, has been tested under Hawaiian conditions during the year. It has proved to be well adapted to the work of top-grafting established trees and is one more method available in this work. One of the great advantages of the method is its extreme simplicity. Bark grafting, which has been so commonly used in Hawaii on hibiscus, consists in the cutting of a scion with one bearing surface and inserting the same under the bark of a branch which has been cut back for the purpose (Pl. II, fig. 1). Branches of the stock may be selected from 1 inch to 3 or 4 inches in diameter, at a time when the bark is slipping. This feature is extremely important, as it is also when budding the mango. This condition of the bark usually occurs when the terminal buds

are just beginning to burst open. A single straight slit about 5 inches long is made in the bark where the branch is cut off. The best scions are of rather small, well-matured wood of the last flush, and the end of the flush is preferable. Such scions are cut with one straight cut, giving a single bearing surface to be placed next to the cambium of the stock. The scion must then be securely tied in place with a strong tie, because the mango bark is thick, and if it begins to dry out it will break a weak strand. The whole scion and the top of the branch used as a stock must then be covered with a paper sack which has been dipped in warm wax. The sack is then tied close to the stock. This covering prevents excessive transpiration of moisture from the scion, which otherwise would be exhausted before a union could take place. The covering may be removed in about three weeks. From 50 to 75 per cent of the scions so inserted, under favorable conditions, may be expected to grow.

With this method available, as well as others which have been described in earlier reports and bulletins, there certainly is no good reason for continuing to allow vigorous trees to produce the worthless fruits which many now yield. The common Hawaiian mango is so inferior to some of the newer varieties that for this reason alone it should be largely replaced. The fact that the Hawaiian variety is so extremely subject to attacks of the Mediterranean fruit fly that few fruits escape, is a further reason for reducing the number of this variety and substituting the Pirie or other resistant varieties.

THE AVOCADO.

The avocado is one of the few fruits that is attacked by the fruit fly to so slight a degree that the injury is practically negligible from the standpoint of fruit production, although the pest has interfered with the marketing of this fruit on the mainland of the United States. Hawaii, however, has been of assistance to the mainland in the establishment of the avocado industry there, the results of most experimental work in Hawaii being of use in Florida and southern California. Many of the Hawaiian seedlings suffered severely in the frost of southern California in the winter of 1913. Some, however, the Nutmeg, for example, have shown considerable resistance to cold. Among the Hawaiian seedlings which are attracting attention in California are the Solano and the Meserve.

The Macdonald, the parent tree of many of the round, hard-shelled winter seedlings, has attracted some attention this year by its remarkable keeping qualities. Fruits were kept in the horticultural laboratory for 16 days without any refrigeration, and at the end of this time were in a perfect state of preservation. These winter fruits are most promising because of their season, and the hard-shelled character is greatly in their favor.

PROPAGATION EXPERIMENTS.

The method of bark grafting applied to the mango has also been tested on the avocado, but has not, up to the present time, proved satisfactory. Scion budding, however, which is quite similar in character, has given satisfactory results. This consists in inserting a scion in a T-shaped incision in the stock. The stocks used for this purpose have been from 1 inch to 4 inches in diameter. The T-shaped incision is made in the same manner as for shield budding, but is much larger. The scion consists preferably of a short piece at the end of a branch from a mature tree which is not growing too rapidly (Pl. II, fig. 2). This scion is prepared by a single cut, and is inserted in the incision, bringing one surface only into contact with the cambium of the stock. It is then tied in place and waxed with a firm grafting wax which will not run when heated by the sun.

This method of propagation appears to have two points in its favor. It affords a means of propagating from old bearing trees which frequently do not produce good bud wood unless they are severely cut back and forced to do so. Scions, however, may be taken from the terminals of slow-growing branches on which there is no material for ordinary shield budding. A further point in favor of the method is that it can be used to work into branches of considerable size, whereas for shield budding it would be necessary to cut back the stock and await the growth of new shoots in which to insert the buds. It is not intended to imply that this method is preferable to shield budding even for top-working trees, but that it may be rendered serviceable under certain conditions.

MULTIPLE-STEMMED SEEDLINGS.

It is a well-known fact that many avocado seeds send up numerous stems. It has been suggested that some of these might be the result of multiple germs. All the multiple-stemmed seedlings which have been studied up to the present time have indicated that there has been a single central stem and the others have arisen from buds on this stem beneath the surface of the ground and in many cases within the seed.

THE PAPAYA.

The work of the breeding of papayas was resumed along the lines indicated in earlier annual reports and in a bulletin of the station.[1] There are no conclusions of special moment to report at present. A number of crosses and close pollinations have been made to secure information on questions arising in earlier work. It is very interesting as well from a practical as from a scientific point of view to

[1] Hawaii Sta. Bul. 32 (1914).

FIG. 1.—HONOLULU'S OLDEST LITCHI TREE.

FIG. 2.—MANGO SEEDLINGS IN FLOWER, LESS THAN 9 MONTHS OLD.

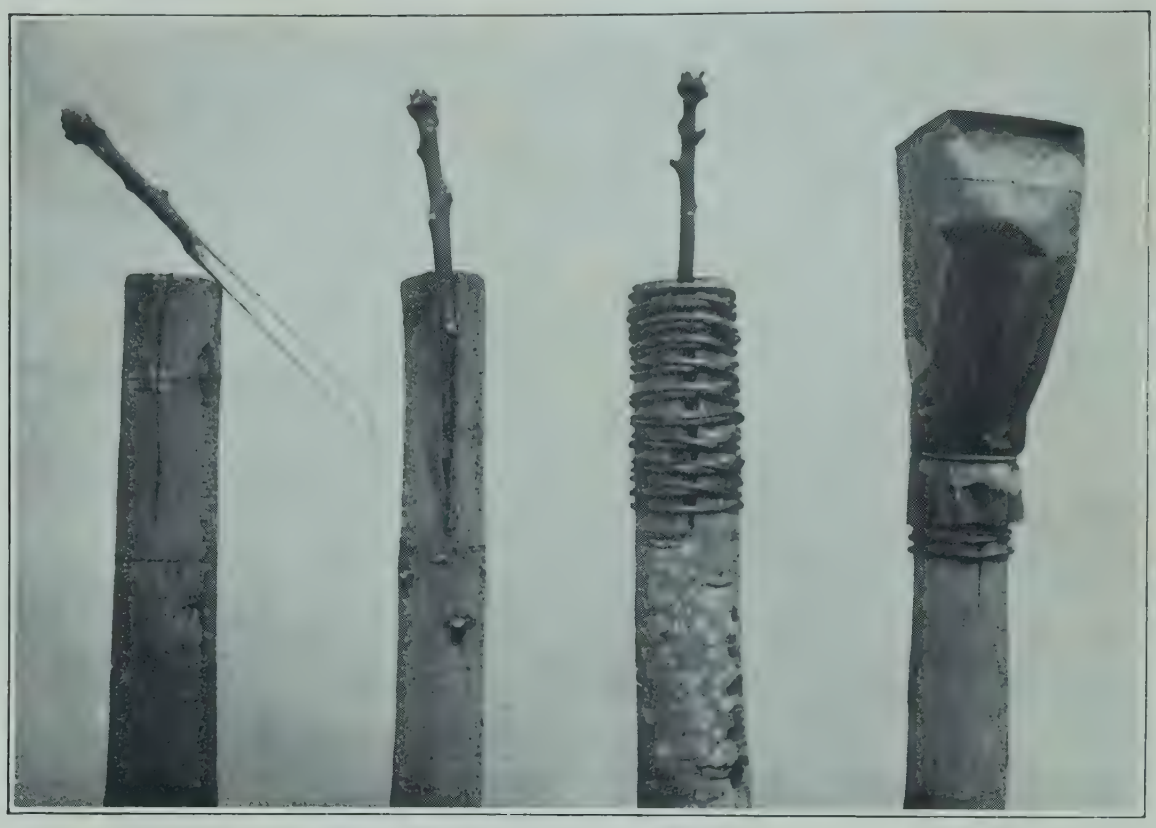

FIG. 1.—BARK GRAFTING THE MANGO.

FIG. 2.—SCION BUDDING APPLIED TO THE AVOCADO.

learn what are some of the factors determining sex in a species producing both dicœcious and hermaphroditic stocks. Will the pollen from a hermaphrodite flower produce offspring that will be almost exclusively fruit bearing, either pistillate or hermaphrodite? To throw light on this and related questions, pollinations have been made as follows:

Flowers of pistillate trees of dicœcious stocks have been fertilized with pollen from hermaphrodite flowers of the elongata form. Flowers of pistillate trees of the hermaphroditic stock have received pollen from staminate trees. Pistillate trees of dicœcious stocks again have been fertilized with pollen from hermaphrodite flowers of the pentandria forms, both oval and pyriform. The possibility of perfecting such fertilizations had in most cases been determined in earlier experiments, but the sex of the progeny has not yet been observed.

A series of close pollinations also has been begun, wherein hermaphrodite flowers of elongata form have received their own pollen exclusively, the purpose being to initiate close breeding.

A number of cross-pollinations also has been made with a view to determining, if possible, and combining unit characters pertaining to flavor, keeping qualities, uniformity in shape, and bearing habits.

CITRUS ORCHARD.

In the citrus orchard many varieties are now in bearing and making a satisfactory growth. Practically all these varieties have been introduced as bud wood and have been worked upon home-grown stocks, thus building up a supply of all the leading varieties of orange, lemon, lime, and grapefruit. A limited amount of bud wood of the following varieties, now bearing, is available: Oranges—Bahia, Bouquet des Fleurs, Golden Buckeye, Golden Nugget, Mediterranean Sweet, Navelencia, Ruby, Scented, Thompson, Valencia, Dancy, King, Willowleaved, and Satsuma; pomelos—Duncan, Imperial, Marsh, McCarty, Royal, and Triumph; lemons—Eureka, Genoa, Lisbon, Ponderosa, and Villafranca; and limes—Kusaie and Tahiti.

WOOD OIL AND KUKUI.

The commercial possibilities of the oil of kukui, *Aleurites moluccana* (*A. triloba*), and of the China wood oil, *Aleurites fordii* (*A. cordata*), have recently attracted considerable attention. It is claimed by some manufacturers that a blend of these two oils is preferable to either. It has been suggested that the hybridizing of these species might result in new forms that might combine the desired characters in a way superior to either of the parents. In bear-

ing habits the China wood-oil tree appears to be quite inferior to the kukui, which bears in clusters, while the Chinese tree produces usually only one nut at the end of each branch, where there is ordinarily found one pistillate flower surrounded by several staminate flowers.

Mr. Valentine S. Holt, assistant horticulturist, was requested to attempt the hybridizing of these species. From 37 cross-pollinations, in which *A. fordii* was used as the female parent, 26 fruits are now set. On *A. moluccana* there are 94 fruits, the flowers of which received pollen from *A. fordii* only. In neither case has it yet been proved that parthenocarpic or parthenogenetic development does not occur in these species, but it appears probable that there is an affinity between them which may be ultilized in hybridization.

DISTRIBUTION OF SEEDS AND PLANTS.

A large number of valuable grafted and budded fruit trees have been distributed to different parts of the Territory, and some have been sent to the mainland and to foreign countries. These have consisted chiefly of mango and avocado, with a few lemons, limes, oranges, and grapefruit. Except in case of exchange, it has been the custom to make a charge for these to cover in part the cost of propagation and handling. By reason of a recent act of Congress, all money now received from sales of products reverts to the Treasury of the United States and does not become available for the use of the experiment station. It thus becomes impossible to recover expenditures made in propagation. For this reason and because other funds are not available, it will be necessary largely to discontinue this work, except as it relates to the introduction and establishing of new and unusual varieties.

The same applies even more strongly to the distribution of hibiscus cuttings. The new varieties of these ornamentals which have been originated here have been distributed in numbers aggregating hundreds of thousands at a nominal charge and may now be seen in all parts of the Territory, while they add to the beauty of many tropical lands. These flowers of rare and delicate beauty will be an asset to the Territory far exceeding all that they have cost. The time has come, however, when the future distribution of the plants and cuttings should be put on a commercial basis.

It has become necessary greatly to reduce the number of hibiscus plants at the experiment station, the land, and more particularly the water, being required for other plants. One plant of each of about 500 or 600 varieties, however, will be retained, while the others will be placed along the public highway at Army posts and public parks where they will benefit the largest number of observers.

Papaya seeds of the varieties bred here have been distributed to a large number of applicants. This will be continued in conjunction with the breeding work.

Seeds of various other economic plants have been distributed, among which may be mentioned roselle, *Carissa grandiflora*, Annonas, Carambolas, and star apples.

Bud wood of citrus varieties has also been sent wherever it has been requested.

EXTENSION WORK IN HORTICULTURE.

The knowledge of budding and grafting is not so general here as in countries where there is large commercial orcharding. Through various methods of extension work, the art is being taught which will make of more service the large collection of varieties at the station. Assistance was given by instruction and demonstration at the summer school for teachers. A trip was made by the horticulturist to the island of Maui, chiefly in the interest of this work. Another trip was made to Hilo to assist in the county fair. The horticulturist is now acting in an advisory capacity in connection with the present effort of the Territorial marketing division to place Hawaiian pineapples in the mainland markets in much larger quantities than heretofore, and thus relieve the situation of the growers who are unable to dispose of their crop.

NEEDS OF THE HORTICULTURAL DEPARTMENT.

The greatest needs of the horticultural department of this station at present are land and other facilities for culture experiments with pineapples and bananas. These are the two fruits of commercial importance for export, and at present they are the only fruits that are allowed entrance from Hawaii to the mainland markets. There is great need for field experiments with both of these crops, but none of the land at the experiment station furnishes normal conditions for them. It is hoped that funds may be made available for the leasing of a suitable tract of land upon which to begin this work.

REPORT OF THE ENTOMOLOGICAL DEPARTMENT.

By D. T. Fullaway.

The entomologist of the station was absent on leave from July 1, 1914, to May 31, 1915. During this time he was in the employ of the Territorial Board of Agriculture and Forestry, being engaged in the prosecution of the general campaign development of parasites of the Mediterranean fruit fly, a work which has met with considerable success.

The close proximity of these two stations to one another made it possible for the entomologist to keep his office open at the Federal experiment station and to attend to his routine work of correspondence and maintenance of the insect collection, which was greatly increased by material obtained from abroad.

During the month of June, 1915, most of the entomologist's time was spent in studies in connection with *Sierola* spp., the natural parasites of various species of Lepidoptera.

While the repeated absences of the entomologist from the station in connection with the Territory-wide insect parasite campaign has to some extent interfered with the work of independent investigation, it is believed, however, in view of what has been accomplished, that the agricultural interests of the islands have been better served than they would have been had the entomologist remained at the station engaged in individual work with parasites of the insect enemies of the agricultural and horticultural crops, or in other lines of entomological activity.

REPORT OF THE CHEMICAL DEPARTMENT.

By Wm. T. McGeorge.

During the past fiscal year Dr. W. P. Kelley resigned as head of the department to become professor of agricultural chemistry at the Graduate School of Tropical Agriculture and Citrus Experiment Station at Riverside, Cal. The work of the chemical department has proceeded with little interruption along the same lines as outlined in previous reports.

The investigation of scientific soil problems, having a very practical significance in the islands, has received the continuous attention of the staff, while all miscellaneous routine analyses have been made with as little interruption of the above work as possible. Marked progress has been made toward a thorough understanding of the peculiar properties, both physical and chemical, of Hawaiian soils.

FIXATION OF FERTILIZERS.

During the fiscal year 1914 experiments on the fixing power of Hawaiian soils were completed, and the results were issued during the past year as a bulletin of the station.[1]

Due to the highly basic character of these island soils, the fixation of phosphoric acid is much higher than that of the other elements. The results show that the best method of application of the phosphates is just before planting. The soluble form should ordinarily be used.

The fixation of potash is apparently controlled by the amounts of lime and magnesia present, and is quite marked. Some loss by leaching is possible, however, if the potash is applied in too large quantities.

With ammonia nitrogen, while the point of saturation is higher, the fixation is not so strong as that of potash. Soils rich in humus retain the ammonia and also the potash better than the red clay type. This is probably due to interaction with the complex "humates."

The Hawaiian soils retain little, if any, of the nitrogen in the form of nitrate. Some highly organic soils, however, react with and fix some of the nitrate solution. Air drying, heat, and the use of antiseptics have little influence on the fixing power of the soil.

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[1] Hawaii Sta. Bul. 35.

BACTERIOLOGICAL INVESTIGATIONS.

The results obtained by Dr. Kelley in the study of bacterial action in Hawaiian soils were published during the year as a bulletin of the station.[1]

Due to the unusual character of the Hawaiian soils, the decomposition of organic nitrogen compounds into forms available for plant food is of considerable importance. The lime-magnesia ratio as influencing nitrification being a subject of much controversy, an investigation was made of the effect of magnesia on nitrification.

Observations show that nitrification does not take place in most Hawaiian soils unless oxidizing conditions are maintained by tillage. Besides aeration, virgin soils also require weathering for several months before the nitrifying bacteria will become active.

The effect of heat and antiseptics was also investigated. Partial sterilization probably makes available, through alterations in the colloidal film, new stores of food and organic material to the surviving organisms, and thus stimulates bacterial action. The effect of aeration also is partly due to the same cause assisted by granulation and oxidation.

The lime-magnesia ratio does not seem to be of much importance in Hawaiian soils. Magnesium carbonate favored ammonification, while calcium carbonate stimulated nitrification in some instances. Dolomitic and calcareous limestone will probably produce similar effects on the availability of the nitrogen in Hawaiian soils.

For any system of permanent agriculture on Hawaiian soils, rotation of crops, including green manuring, must be strongly insisted upon in order to maintain the best aeration possible.

PHYSICAL STUDIES OF HAWAIIAN SOILS.

In another bulletin issued during the year,[2] the results are given of an extensive study of the physical properties of Hawaiian soils and the effect of fertilizers on these properties. Since it is impossible to measure by chemical analysis the presence of a normal application of fertilizer in the soil, and since it has been shown that the addition of salts and fertilizing materials affects the structure of the soil materially, it is suggested that these measurements of the physical effects of applications of fertilizer would be of considerable importance in determining the value of the fertilizer salts.

In most instances the fertilizer salts increase hygroscopic moisture, lower vapor pressure, and increase the cohesion of the soil particles. Capillarity is diminished in clay soils but increased in sandy soils by the addition of salts. Fertilizers increase the resistance to percolation, which takes place most rapidly in sandy soils.

[1] Hawaii Sta. Bul. 37. [2] Hawaii Sta. Bul. 38.

SOIL SURVEY.

Previous to the resignation of Dr. Kelley, a paper entitled "The Soils of the Hawaiian Islands" was prepared and submitted for publication as a bulletin of the station.[1] In this bulletin the work of about six years' investigation upon Hawaiian soils is taken up, dealing with the composition of the various types of soil found on the islands and the practical bearing and application of the various scientific investigations which have been carried on in this laboratory.

THE ORGANIC PHOSPHORIC ACID OF RICE.

It has been known for some years that phosphoric acid exists in grains in organic combination with inosite and some base, and, as such, is taken into the animal system as a supply of phosphoric acid to the body. Because of its physiological value, the organic phosphoric acid which is known as phytin or phytic acid has received considerable attention, and a number of investigators have studied its composition and occurrence in grains.

It was believed that a study of phytin in rice would be of interest, since rice is one of the principal crops raised in Hawaii, and is valued as food by many of the inhabitants. The isolation and study of the composition of the phytin in rice was made by Miss Alice R. Thompson, assistant chemist, and the detailed results have been published elsewhere.[2] It was found that most of the phytin in rice exists in the outer layer of the grains, and in the process of polishing the rice practically all the phytin is removed. Phytin was isolated from unpolished rice and from bran, but none could be obtained from polished rice. The total phosphorus was determined in the samples and found to be 2.29 per cent in the rice bran, 0.321 per cent in unpolished rice, and 0.140 per cent in polished rice.

The phytin was obtained by treating the sample bran and unpolished rice with 0.2 per cent hydrochloric acid and precipitating with barium hydroxid. The white barium salt was washed, dissolved, and reprecipitated several times with barium chlorid and alcohol. The composition of two samples of the tribarium salt was determined and the barium, phosphorus, carbon, and hydrogen contents compared with that of the tribarium-inosite-hexaphosphate salt reported by Anderson in other grains.

Special attention was paid to several methods of determining barium in the salt, and precautions were noted to be observed in obtaining a pure barium sulphate precipitate from solutions of the salt.

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[1] Hawaii Sta. Bul. 40 (1915).

[2] U. S. Dept. Agr., Jour. Agr. Research, 3 (1915), No. 5, pp. 425–430.

Inosite was insolated from the barium phytate and its melting point determined.

THE EFFECT OF ARSENITE OF SODA ON THE SOIL.

The increased use of arsenite of soda spray as a means of killing weeds led to a study of the injurious effect of this chemical. Attention was given to its influence upon plant growth, on the biological and physical properties of the soil, and its chemical action toward the soil constituents. The soils studied were found to have a very strong fixing power for arsenic. A sample of soil from Nahiku, Maui, on which weeds had been sprayed for five years at the rate of three sprayings per year (5 pounds arsenic per acre per application) showed on analysis that all the arsenic was held in the top 4 inches of soil. Accounts of this work have been published.[1]

THE AVAILABILITY OF PHOSPHATES.

This work, also mentioned in the last annual report, has been completed and submitted for publication as a bulletin of this station. It was broadened considerably more than was at first anticipated in order to study phosphates more thoroughly from all angles. The availability of all the commercial phosphates was compared; the solubility of phosphates naturally occurring in Hawaiian soils was studied; the fixation of phosphoric acid by the soil received some attention; and, finally, as an appendix, a modified method for determining phosphoric acid in local soils was submitted. The latter method was adopted after nearly 250 phosphate determinations.

The importance of the above work is realized when it is known that the phosphate content of Hawaiian soils is, with rare exceptions, ample for good plant growth, but owing to its extremely unavailable condition the addition of this type of plant food as a fertilizer is often desirable.

LEGUMES AS GREEN MANURE.

This station has consistently advocated the use of legumes as a green manure. The benefit derived from legumes is due to both chemical and physical effects on the soil; the nitrogen content is increased and the texture of the soil is improved by the added humus. The red clay Hawaiian soils, especially, need green manure to prevent puddling and to aid aeration.

In order to determine the relative value of the various legumes, pot experiments were made by Miss Alice R. Thompson, assistant

[1] Hawaii Sta. Press Bul. 50 (1915); U. S. Dept. Agr., Jour. Agr. Research, 5 (1915), No. 11, 459–463.

chemist. One hundred and thirty-two pots were filled with a calcareous soil and the same number with a lime-poor soil. Thirty-two varieties of legumes were grown, one variety being apportioned to four pots of each soil type. Four pots of each soil were thus left as checks. At maturity the duplicate plants in two of the four pots were removed, weighed, and the nitrogen determined. Nitrates, nitrites, ammonia, and total nitrogen were determined in the soil and compared with the check pots, after deducting the nitrogen added in the legume seed. Two pots were left of each variety of legume planted, the plants being turned under to decompose. The quantity of nitrogen added to the soil will be determined later.

In all instances the nitrates in the soil from which the legumes had been removed was much lower than in the check soil. But these soils low in nitrates on standing in the open air soon equaled in nitrate value the soil of the check pots. Where much legume material was turned under the nitrates in the soils were greatly increased.

The plants grown in soils deficient in lime made a poor growth and had a lower nitrogen content, calculated on a water-free basis, than the plants grown in soils rich in lime. In a second experiment lime was added to the lime-poor soil, but the plants grown in this soil were also undersized and low in nitrogen. In a third experiment phosphate fertilizer was added to the lime soil and plants again grown in these pots. Results are to be obtained in a few months from the last series.

THE ANALYSIS OF HAWAIIAN SOILS.

In the course of the examination of about 600 soil samples in this laboratory peculiarities in soil types have been met which necessitated slight modification in the method of soil analysis as outlined by the Association of Official Agricultural Chemists. Chief among the inhibiting factors may be mentioned the high content of iron, aluminum, titanium, and manganese.

The modifications found to produce best results are submitted herewith, as are also some data showing the influence of time upon the solvent properties of hydrochloric acid. It was hoped that, in view of the low silica content, the time of digestion could be shortened to advantage without lowering the thoroughness of the extraction.

Four soils were chosen for this work—a sandy soil (No. 1), a red clay (No. 2), a silty soil of high humus content (No. 3), and a brown clay (No. 4). These soils were digested on the steam bath with hydrochloric acid (specific gravity, 1.115) for 1, 4, 6, 8, 10, and 15 hour periods. The results are given in the table following.

Effect of time of digestion of soil in hydrochloric acid (specific gravity, 1.115) on thoroughness of extraction.

Soil No.	Time.	Insoluble residue.	Iron oxid.	Alumina.	Titanic oxid.	Manganomanganic oxid.	Lime.	Magnesium oxid.	Potash.	Sulphur trioxid.	Phosphoric acid.
	Hrs.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
1	1	45.30	15.04	9.64	1.36	0.22	3.39	8.74	0.19	0.26	1.09
	4	48.12	16.44	9.21	1.41	.30	3.09	.....	.58	.21	.90
	6	38.06	16.36	14.79	1.61	.17	3.09	10.60	.62	.22	1.05
	8	37.10	16.80	14.44	1.71	.23	3.27	11.50	.72	.25	.96
	10	37.98	16.94	13.53	1.76	.17	3.58	10.50	.82	.35	.99
	15	37.61	17.80	13.33	1.76	.18	3.21	11.10	.75	.32	.99
3	1	37.24	9.08	10.90	1.07	.12	3.52	.91	.62	.35	2.35
	4	34.83	9.20	13.89	1.07	.11	4.00	1.02	.45	.34	2.31
	6	34.41	9.72	14.51	1.12	.12	3.76	.97	.41	.32	2.28
	8	34.15	9.44	14.91	1.12	.12	3.69	1.03	.52	.38	2.39
	10	34.30	9.88	14.73	1.12	.20	4.14	1.11	.58	.35	2.29
	15	34.38	9.72	14.55	1.07	.13	3.90	1.02	.59	.38	2.26
2	1	46.05	14.92	12.35	.78	3.03	.52	.28	.....	.26	.27
	4	35.58	16.16	20.83	.97	2.81	.54	.32	.26	.27	.37
	6	32.90	15.36	24.03	1.02	2.89	.52	.34	.38	.23	.32
	8	31.38	16.08	25.25	1.02	2.48	.58	.58	.44	.26	.44
	10	30.89	16.52	25.94	1.07	2.53	.65	.57	.43	.29	.42
	15	29.93	17.40	25.01	1.07	2.63	.63	.59	.53	.28	.50
4	1	46.10	24.64	10.67	3.12	.04	.26	.74	.11	.19	.53
	4	38.77	29.92	11.48	3.90	.04	.30	1.05	.16	.22	.43
	6	34.59	30.00	11.96	4.19	.04	.30	.94	.20	.21	.40
	8	35.89	32.64	11.72	4.19	.07	.42	1.23	.23	.24	.36
	10	35.88	30.44	13.34	4.19	.08	.36	1.21	.22	.22	.50
	15	35.05	31.60	13.07	4.19	.04	.41	1.30	.26	.26	.51

As previously mentioned, it was hoped that a reduction in the time of digestion could be made for local conditions, but apparently best results are obtained by digesting for 10 hours. However, the conclusion is plainly evident that the use of hydrochloric acid of this strength is primarily a study of solution and not of ultimate composition, when applied to Hawaiian soils. A digestion of 10 hours by no means results in a complete extraction in all soils.

MODIFICATION IN ANALYSIS.

ACID DIGESTION.

Digest 10 grams of soil for 10 hours in a 300-cubic centimeter soil digestion flask with 100 cubic centimeters of hydrochloric acid (specific gravity, 1.115) in boiling water. Dilute with 50 cubic centimeters of water, filter while hot into a 500 cubic centimeter volumetric flask, and wash the residue until the filtrate is nearly 500 cubic centimeters. Cool to room temperature and make to volume (solution A).

INSOLUBLE RESIDUE.

Dry the insoluble residue and ignite to constant weight.

IRON, ALUMINUM, AND TITANIUM.

Take 50 cubic centimeters of solution A, add a few drops of nitric acid, boil for a few minutes, remove from hot plate, make

slightly alkaline with ammonia, and boil off the excess. Filter, wash several times with hot water, and transfer the precipitate and filter to the original beaker. Dissolve by boiling in dilute hydrochloric acid. Reprecipitate as before, filter, and wash free of chlorid. Dry, ignite, and weigh the precipitate as ferric oxid, alumina, titanium oxid, and phosphorus pentoxid. Reserve the filtrate (solution B) for determining manganese, calcium, and magnesium.

Treat a second aliquot of 50 cubic centimeters of solution A in the same way up to the point of ignition of the ammonia precipitate. Instead of igniting, transfer the precipitate to the original beaker and dissolve by boiling in dilute sulphuric acid. Transfer to a 100-cubic centimeter volumetric flask, cool, and make to volume. Determine the iron by titrating 25 cubic centimeters of this solution with tenth-normal potassium permanganate in the regular way. Determine titanium by the colorimetric method as follows: Transfer 5 cubic centimeters of the sulphuric-acid solution to a 50-cubic centimeter Nessler tube, dilute, and add 5 cubic centimeters of dilute sulphuric acid, 5 cubic centimeters of hydrogen peroxid, mix well, and compare with a standard prepared at the same time from a solution of titanium sulphate. The filtrate from the second aliquot should be reserved for the determination of sulphate, soda, and potash (solution C).

Since potassium permanganate oxidizes titanium as well as ferrous iron, it is necessary to calculate the volume of permanganate required to oxidize the titanium present and to make a correction accordingly in calculating the iron. The aluminum is determined as usual by difference.

MANGANESE.

Concentrate solution B to about 150 cubic centimeters, add about 3 cubic centimeters bromin (undiluted), allow to stand 5 minutes, add an excess of ammonium hydrate, and heat to boiling. Let stand overnight, filter, wash with hot water, dry, ignite, and weigh as mangano-manganic oxid (Mn_3O_4).

CALCIUM.

Evaporate the filtrate to dryness and drive off the ammonium salts. Dissolve the residue in dilute hydrochloric acid and determine calcium in the regular way. The removal of the large excess of ammonium salts is necessary in order that any unprecipitated manganese will be thrown down.

MAGNESIUM.

Magnesium may be determined by precipitation in the regular way from the above filtrate direct.

SULPHATES.

Best results have been obtained by removing the iron and aluminum previous to the precipitation of the sulphate. Hence, solution C is evaporated to dryness, ammonium salts volatilized, the residue dissolved in dilute hydrochloric acid, and the sulphate determined in the regular way with barium chlorid.

POTASH AND SODA.

From this point the analysis may be carried out on the above filtrate according to the official methods without modification.

PHOSPHORIC ACID.

To 50 cubic centimeters of solution A add a few drops of nitric acid and heat to boiling. Make alkaline with ammonium hydrate, boil off excess, filter, and wash. Transfer filter and contents to a beaker and boil with dilute nitric acid, nearly neutralize with ammonia, add 50 cubic centimeters of molybdate mixture with constant stirring, and allow to stand in water bath for four hours at 55° C. From this point proceed as in the official method.

HUMUS.

Modifications in the method of determining humus are dealt with in full in a press bulletin of this station.[1]

SOIL COLLOIDS.

Frequent mention has been made in previous publications of this station of the presence of colloids in Hawaiian soils. A condition which apparently arises through the formation of this class of bodies was given some attention during the past year.

The clay soils may be divided into two classes: Class 1, in which the alumina is higher than the iron and the titanium is very low; and class 2, in which the alumina is lower than the iron and the titanium is high. The former class is the one showing the more colloidal properties, and in spite of this contains fewer clay particles than the latter class. In the analysis of the hydrochloric-acid extract, considerable difficulty arises upon filtering the ammonia precipitate of iron, aluminum, and titanic hydrates and phosphates. The inhibiting factor presents itself in the form of a colloidal gel, rendering the washing of the ammonia precipitate extremely difficult. This gel is insoluble in cold acids, and hence in redissolving the precipitate it is necessary to boil it in an acid solution.

[1] Hawaii Sta. Press Bul. 33.

A sample of this colloidal gel was analyzed with the following results:

	Per cent.
Silica (SiO_2)	1.04
Phosphoric acid (P_2O_5)	1.02
Manganomanganic oxid (Mn_3O_4)	.73
Titanic oxid (TiO_2)	.66
Ferric oxid (Fe_2O_3)	9.37
Aluminum oxid (Al_2O_3)	87.18

Apparently this colloid is aluminum hydroxid, the physical properties of which are influenced by a small amount of silica and titanium. In all soils which contain iron in excess of alumina, this colloidal gel is never formed, but in soils of high aluminum content it is invariably present.

THE EFFECT OF PARTIAL STERILIZATION ON PLANT GROWTH.

Considerable study has been devoted to the effect of partial sterilization upon Hawaiian soils. A previous publication[1] treats of the effect of heat upon the physical and chemical properties of the soil, while the biological influences are thoroughly dealt with in the bulletin referred to on page 30.

During the year the above work has been supplemented by pot experiments. Heretofore the influence of sterilization on plant growth has been demonstrated in an experimental way in Hawaii only in districts where brush, accumulated in clearing land, has been burned upon the soil. In these cases a remarkable influence upon plant growth has been noted.

The pot experiments were carried out as follows: Two types of soil were used, a red clay and a sandy soil high in organic matter. These soils were treated as follows: Heated in sunlight, in an oven at 80°, 110°, and 165° C., and in an autoclave at 10 pounds pressure. Those heated in the oven were left for 2 hours, that in the autoclave for only 1 hour. In addition soils were treated with the following antiseptics at the rate of 10 cubic centimeters per kilogram: Carbon bisulphid, chloroform, and toluene. Also a check was run with the above in which the soil fresh from the field, that is, undried in the air, was used. These pots were planted in duplicate to onions, millet, and cowpeas.

The influence upon plant growth is well shown in the accompanying illustration. (See Pl. III.) The plants as shown are three months old.

The above illustrations represent plant growth upon the sandy soil. The results upon the red clay soil, while different in certain instances,

[1] Hawaii Sta. Bul. 30 (1913).

as a whole are very much the same. A very poor stand was obtained in all the pots of red clay soil, for which reason no illustrations are submitted.

ONIONS.

The influence of partial sterilization upon onions was very marked. Volatile antiseptics produced a wonderful increase, while heating in the autoclave was productive of a substance evidently toxic toward this plant. (See Pl. III, fig. 1.)

MILLET.

An increase in vigor of the millet plant was correlated with an increase in temperature at which the soil was sterilized. The plants are more vigorous in the pots sterilized by heat than those sterilized by antiseptics. It appears that the organic substance having a toxic influence upon onions is without effect upon millet, for in the pot heated in the autoclave, the plants are as vigorous as any others. (See Pl. III, fig. 2.)

COWPEAS.

In case of cowpeas, the increase in temperature at which the soils were sterilized resulted in a steady decrease in vigor. While the volatile antiseptics lowered the vigor to a slight extent, their influence is not so marked as heat. These results clearly show the intimate relationship between leguminous plants and bacterial life in the soil. (See Pl. III, fig. 3.)

REPORT OF THE AGRONOMY DEPARTMENT.

By C. A. Sahr.

The work of this department consisted largely in the continuation of the lines followed in previous years. The unusually long droughts handicapped the agronomic work on fields not provided with irrigation facilities.

Repeated failures with both sweet and field corn on the station grounds clearly demonstrated the necessity of an adequate irrigation system to insure this crop against irregular seasons when grown outside of the corn belt of the islands. While many insects attack corn, the damage they do is nominal if the plant is grown under favorable conditions. As soon as the crop becomes checked in growth by drought and the whipping action of heavy winds, insect attacks render the crop unprofitable even as silage.

A fertilizer and rotation test with Reid Yellow Dent corn No. 901 was begun, the crop being planted October 1, 1914, and harvested January 9, 1915. The results were so contradictory that no generalizations can be made from them.

SOIL AERATION TESTS WITH RICE AND TARO.

Experiments to ascertain the effects of soil aeration between crops upon the actual yields of submerged crops were conducted with rice and taro.[1]

The plat under test was divided, one-half being given a deep plowing early in June to allow aeration of the soil until the time of planting, while the remaining half or check plat was left untouched until plowed September 2. Both plats were planted to rice September 4, 1914, and the resulting crop harvested December 8, 1914. The aerated plat yielded 83.5 pounds of rice paddy as compared with 71.5 pounds on the nonaerated portion.

A second test, to serve as a check upon the first, was conducted on the same plats. However, the order of the plowing was reversed, the aerated plat of the first test serving as a check plat under the second test. Owing to the late maturity of the previous crops, the aerated plat had but 30 days over the check plat. Both plats were planted to rice on February 18. Here again the yield on the aerated

[1] For results of a study of the effects of aeration on ammonification and nitrification in Hawaiian soils see Hawaii Sta. Bul. 37 (1915).

plat was the greater, 96.25 pounds of rice paddy being harvested from the aerated plat and 78.5 pounds from the nonaerated one.

In the soil aeration tests with taro, the aerated plat was given a deep plowing on June 10, 1913, while the nonaerated plat was plowed on September 10, 1913. Both plats were planted with white taro September 14, 1913, and harvested after a period of 14 months. The results of this test showed a slight increase in the yield of taro and a reduction in the percentage of diseased corms which may be attributed to soil aeration.

These tests are but preliminary work on soil aeration. As the land has been found to be quite unsuitable for definite results, these tests, which were conducted in Nuuanu Valley, have now been transferred to a plat in Waiau, which has been known to be under cultivation of aquatic crops, rice and taro, for 25 years.

Some depression exists among the local rice growers owing to the fact that island-grown rice can hardly compete with the Texas-grown product. At this time many rice growers are hesitating in regard to the further planting of their lands to rice, the inclination being to plant partially to forage crops for maintenance of cattle and hogs. The need of a good system of rotation for this particular type of soil is manifest, and the problem will probably be solved with the cooperation of the more intelligent rice planters.

POTATOES.

Experiments with potatoes included variety, fertilizer, and spraying tests, but the exceedingly dry and hot weather conditions materially affected the results.

In a fertilizer and spraying test with Early Rose potatoes, involving 10 plats of one-twentieth of an acre each, only the 6 lower plats produced plants, the 4 upper plats receiving too small a share of the prevailing light rains to start the eyes properly. This observation was substantiated by actual moisture-content tests taken at a depth of 6 inches in the soils of the upper and lower plats. The soil of the upper plats showed 16 per cent water, while that of the lower plats showed 24 per cent.

The test of spraying with Bordeaux mixture and lime sulphur on Early Rose potatoes resulted in yields of 15 bushels for the check, 25.9 bushels for lime-sulphur spray, and 30.2 bushels per acre for the Bordeaux mixture.

LEGUMES.

Among the new legumes received for trial are three red clovers from Switzerland, Ladino, white clover, and white sweet clover (*Melilotus alba*). These were planted among other legumes on February 18,

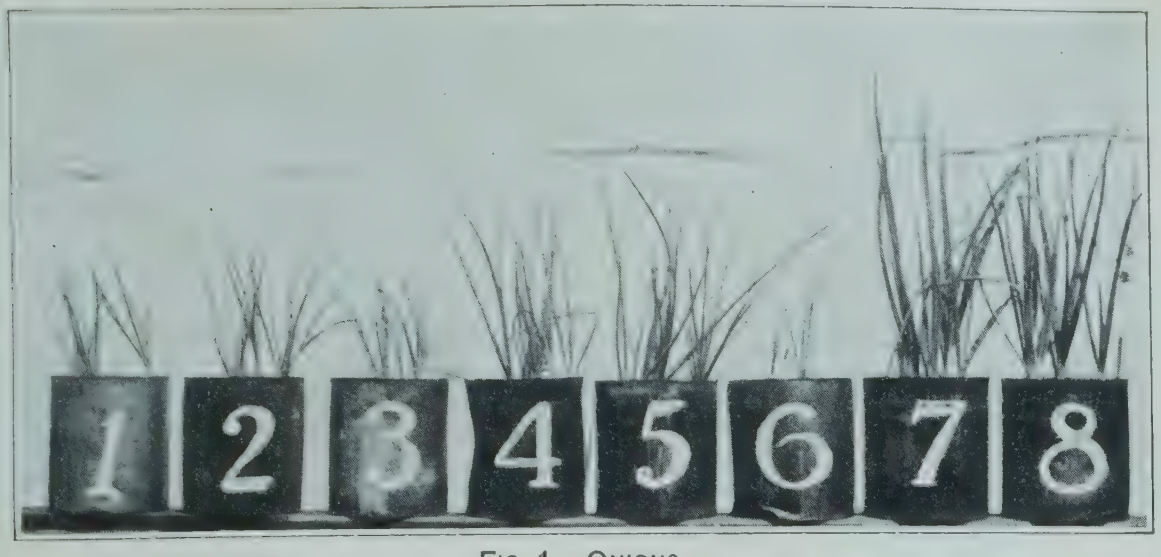

FIG. 1.—ONIONS.

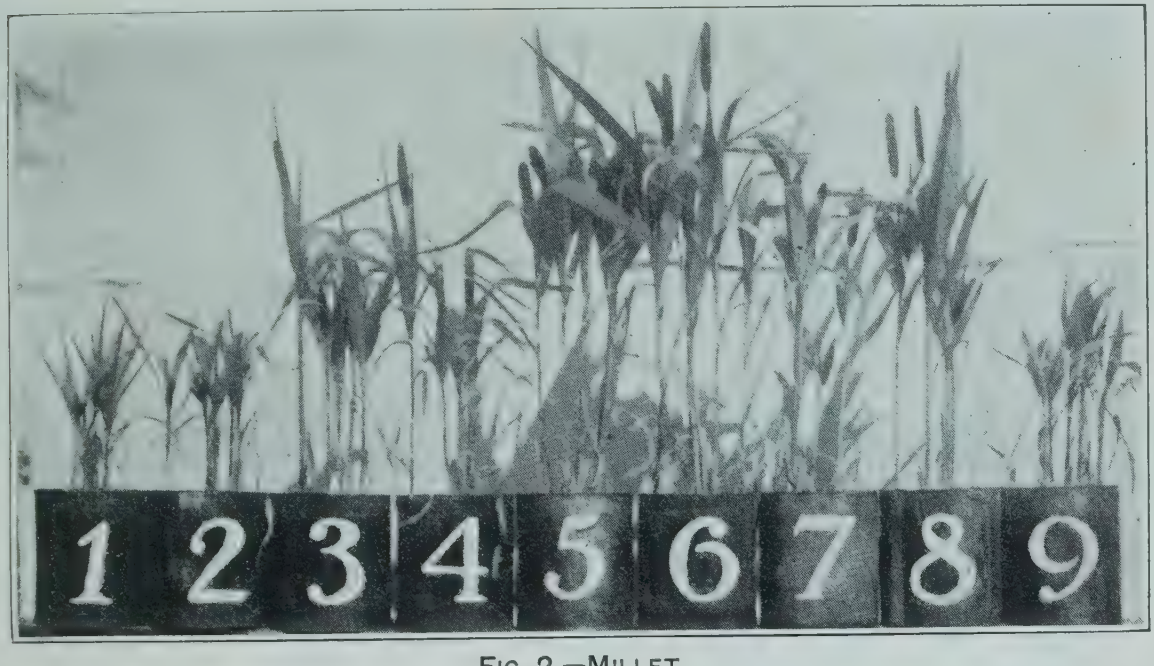

FIG. 2.—MILLET.

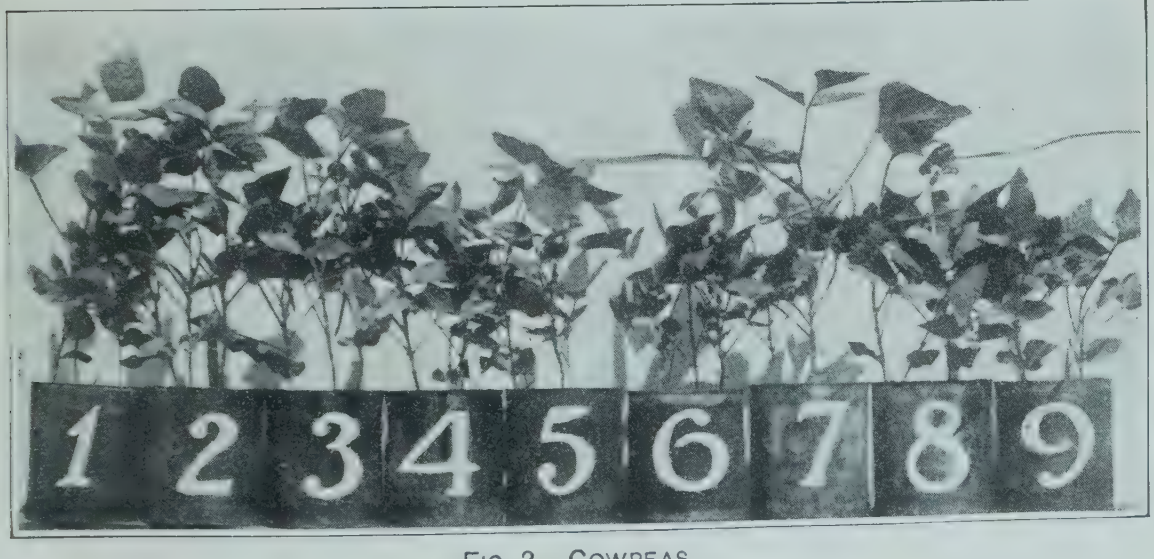

FIG. 3.—COWPEAS.

1, Check; 2, exposed to sunlight; 3, heated at 80° C.; 4, heated at 110° C.; 5, heated at 165° C.; 6, heated in autoclave; 7, treated with carbon bisulphid; 8, treated with chloroform; 9, treated with toluene.

EFFECT OF PARTIAL STERILIZATION OF SANDY SOIL ON PLANT GROWTH.

FIG. 1.—PLAT OF JAPANESE MILLET ON STATION GROUNDS.

FIG. 2.—PARTIAL VIEW OF SEED PRODUCTION TESTS OF LEGUMES VALUABLE FOR GREEN MANURE.

the three red clovers from Switzerland sending out their first blooms during the third week of June, when only a little over a foot in height. All the true clovers (*Trifolium* spp.) are recommended only for high, moist localities. The white sweet clover is very similar to alfalfa, though inclined to bloom considerably later.

Crotalaria mesopontica, introduced here in April, 1914, made a slow growth until fall, attaining a height of 2 feet during the winter months, in which period the plants produced profuse blooms and pods. Another species of Crotalaria (*C. madurensis*) from Ceylon, planted April 15, 1914, had already made considerable growth by July 1. Like the other Crotalarias, this Ceylon variety is likely to earn a place among green-manuring crops for Hawaii. The two wild species of Crotalaria (*C. incana* and *C. striata*) have been planted in green-manuring tests, but fail to respond well to cultivation, the seed not germinating with the first rains, but beginning to appear some weeks later when the soil has become well settled.

In a series of sewings made with jack beans and species of velvet beans, seeds which were sown in early September made the most prolific yields of both green matter and seed. The jack bean, Yokohama bean (*Stizolobium hassjoo*), ashy pod bean (*S. cinereum*), and *S. capitatum*, matured in the middle of January. The Florida velvet bean and Mauritius bean matured one month later.

In a test for yields in forage of alfalfa under natural conditions of rainfall a Spanish alfalfa from Teneriffe and a Utah and Kansas strain of common alfalfa outyielded Peruvian and Turkestan. Given in the order of their merit, the yields in pounds of green forage per annum are: Spanish, 56,362; Kansas common, 52,065; Utah common, 45,245; Peruvian, 35,530; and Turkestan, 30,595.

Semipalatinsk alfalfa or Sholteek (*Medicago falcata*) failed to make a showing equal to that of the ordinary alfalfas or of Japan clover (*Lespedeza striata*).

SMALL GRAINS.

Further experiments with wheat, oats, rye, and barley show but small yields of grain under conditions similar to those on the station grounds. The season required from time of sowing to maturity is 5 to 6 months in duration; therefore the growth is too likely to be interrupted by long periods of drought for successful crops other than those for pasturing or green-manure purposes.

SORGHUMS.

The results of an experiment with a sweet sorghum, a non-saccharin sorghum, and Japanese cane for yields of forage over a period of 453 days were given in the last annual report. The total

yields per acre (green weight) for a period of 26½ months for the sorghum and 27 months for the Japanese cane are: Sweet sorghum, 8 cuttings, 86.55 tons; nonsaccharin sorghum, 6 cuttings, 88.45 tons; and Japanese cane, 3 cuttings, 157.64 tons.

Two other sorghums, African No. 307 (S. P. I. No. 25341) and a durra, No. 760 (S. P. I. No. 27878), have given splendid yields of forage, averaging 15 tons per acre per cutting at periods of 90 to 100 days. Of the sorghums under test for forage yields, Sugar Drip, milo maize, and feterita have shown a tendency to head out too early, or at least before putting out a large amount of leaf surface, the plants appearing weak and spindling. Kafir corn, while stronger growing than either milo maize or feterita, does not seem to show the drought resistance of Sugar Drip, Amber Cane, and the nonsaccharin, long-season African sorghums. Recent observations by the writer have brought to light an inclination among farmers to send to mainland seed firms for sorghum seed without specifying the type of sorghum wanted to supply their particular needs. The seed firms naturally fill such orders with their poorest sellers, usually a kafir or milo maize, which often fail, even with irrigation, to supply profitable yields of forage.

GRASSES.

Of the several forage grasses under trial, Sudan grass still maintains the lead which it gained soon after its introduction into this Territory by its prolific yields of succulent forage. In various tests this grass has yielded from 10 to 40 tons of green forage per cutting, still heavier yields resulting from ideal conditions of soil and rainfall being recorded. Tunis grass has proved valuable as a forage grass at high elevations. In comparison with Sudan at a low elevation, Tunis grass yielded an average of a little less than 4 tons per cutting per acre for six cuttings, while Sudan yielded an average of 14½ tons per cutting per acre for seven cuttings.

Molasses grass (*Melinis minutiflora*) has gained considerable favor in the Hamakua district of Hawaii. The farmers of that district prefer the molasses grass to either Australian water grass or Para grass.

Wilder grass (*Andropogon* spp.), introduced into the Territory by Mr. G. P. Wilder in 1913, has produced excellent results where sown for pasturage. This grass is very slow in its early growth, the first blooms appearing about 120 days after germination. If used as a forage crop, Wilder grass should be cut immediately upon the appearance of the first flowering heads, because the long awns on the flowering glumes interfere with its use as forage. The station plat, planted with roots received from Mr. A. F. Judd in December, 1913,

was cut for seed in June and October, 1914, and in January, 1915, and on being cut for forage May 29, 1915, this plat yielded 11.25 tons of green forage per acre.

Australian blue grass (*Andropogon sericeus*) is another valuable pasture grass for the lowlands. Its habit of growth is very much the same as that of Wilder grass, but it is a little more erect and somewhat less leafy at the bottom. Two cuttings of this grass averaged 9.5 tons green fodder per cutting per acre.

Giant Bermuda grass has met with most requirements of the average ranger for both pasturage and forage. It is adapted to all elevations up to 4,000 feet. Cuttings of this grass set out in soft, moist soil make little headway until the soil has become thoroughly compact. When once started, its growth is persistent.

Teff, Mitchell grass, wallaby grass, side oat grama, Judd, and American buffalo grass (*Bulbilis dactyloides*) have continued to persist under unusual conditions of drought for nearly two years.

BUCKWHEAT.

Further tests with Japanese buckwheat and Silverhull buckwheat were carried out in Nuuanu Valley, where greater moisture and apparently cooler conditions resulted in heavier yields of buckwheat than were obtained in any trial on the station grounds. The Japanese buckwheat matures a week earlier than the Silverhull and yields about 25 per cent more grain.

JAPANESE MILLET.

Trials with Japanese millet, undertaken at various periods, resulted in very good yields of forage when cut green, and of roughage and seed when allowed to mature. (See Pl. IV, fig. 1.) If grown for soiling purposes, millet must be cut when the flowering heads first appear, which is usually about 60 days from planting. Millet matures in 80 to 100 days under ordinary conditions, and its best period for cutting for forage value is limited to 8 or 10 days. Yields of 12 tons of forage per acre when cut green, and 3 tons roughage and 30 bushels of seed per acre when left to mature, are the approximate yields of the station plantings. As a soiling crop, millet is planted to best advantage in November and December, and harvested in January and February, the cool-weather months when sorghum yields are low.

NUT GRASS CONTROL.

The best results in controlling the spread of Japanese nut grass have been accomplished so far by spraying with arsenite of soda. Advantage is gained by spraying when the nut grass is heading out,

thus killing the growth above the surface of the soil and causing the stem below the surface to rot. Spraying in single applications, however, will not kill the underground bulbs, and new shoots will again appear after a week or 10 days. Following each application of arsenite of soda, all dead growth is burned off as soon as it is sufficiently dry, thus leaving the ground bare of growth. The new shoots of nut grass are then more easily accessible to the spray. Persistent spraying at the proper time to prevent seeding may eventually sap the vitality of the underground bulbs, finally killing them.

Other methods of eradication under trial are cutting frequently at the surface and plowing with a disk plow. The results of these methods at this time are not conclusive.

COTTON.

That paying crops of Caravonica "wool" cotton can be grown in the Kona district in spite of the pink bollworm (*Gelechia gossypiella*) is indicated in the continual demand for cotton seed from the homesteaders of that district to extend their cotton fields.

Of the stand of Caravonica "wool" cotton planted on the station grounds in February, 1910, two rows have been retained to furnish data on longevity and yields. The average yield per tree per annum, when grown for four years, has been approximately 1 pound of lint. The rows are 10 feet apart, with the trees 10 feet apart in the row.

Small stands of Sea Island, Egyptian Yuma, and Upland cotton are maintained annually to supply selected seed for distribution.

SEED DISTRIBUTION.

There has been a demand chiefly for soiling and pasture and pasture crop seed, Sudan, Wilder, Australian blue, teff, Tunis, and Mitchell grass seed, while roots or cuttings of Giant Bermuda and some other grasses have been eagerly sought. In the distribution of all seed particular pains have been taken to supply the homesteader with seed of crops particularly suited to his needs and environment. No attempt has been made to supply seed of field or sweet corn other than for trial plantings. A number of the more promising legumes are being grown for seed for limited distribution to farmers for cooperation tests. (See Pl. IV, fig. 2.)

REPORT OF THE EXTENSION DIVISION.

By F. G. Krauss.

INAUGURATION OF THE WORK.

The present agricultural extension work of the station was definitely inaugurated in November, 1914, when the present superintendent was appointed to take charge of the work. This work was provided for by a special fund of $5,000 added to the regular appropriation for the Hawaii Agricultural Experiment Station. Previous to this, the extension work of the station was confined largely to projects provided for by local appropriations by the Territorial legislature. Most of the substations which were of nonexperimental character were provided for in this way. It is hoped eventually to correlate all extension and demonstration work under one head.

Hawaii is peculiar in that it has no established diversified agriculture with its usually associated groups of small independent land holdings so familiar on the mainland. Many efforts have been made to homestead various tracts of the public lands of the Territory, but no examples of markedly successful small farm communities are existent. The reason has been twofold: The establishment of communities of farmers in sufficient numbers to insure their stability can not be hoped for until it has been demonstrated by actual test that a variety of crops other than the few main staples now grown can be produced economically on a commercial scale, and that, various crops having been so grown, a profitable market can be developed for their disposal.

The lack of organized effort is doubtless the chief reason why greater success has not been obtained in the past. The Hawaii Experiment Station, and through it a few scattered farmers, have demonstrated that a large variety of crops now imported from the mainland, as well as many of those peculiar to the Tropics, can be successfully grown throughout the islands. The newly created marketing division has proved that most of such products find a ready sale, either locally or on the mainland, if delivered regularly in good marketable condition and sufficient quantity. It is the object of the new agricultural extension division to correlate these facts and to make known these and various other facilities of the United States Department of Agriculture for the direct benefit of the farmers of

Hawaii. The success that will accrue from this movement will be measured in large part by the extent to which the farmer will cooperate with the extension division.

The establishment of the Glenwood and the Hilo substations on Hawaii, the Nahiku substation on Maui, the Waipio substation on Oahu, and the Homestead substation on Kauai, together with the marketing division in Honolulu, constituted the initial cooperative effort made to aid the farmer in realizing a more normal and profitable agriculture. The establishment of a demonstration farm in the midst of the Kuiaha-Pauwela homestead tract, near Haiku, on the Island of Maui, is the direct outgrowth of an organized effort of the homesteaders to obtain this Government cooperation for which the extension division was created. It may be said to have been born of economic necessity. A group of some forty American families have cast their lot in an agricultural venture which promised well because of its favorable location and the apparent assurance of a safe and profitable crop. The successful culture of pineapples had already been demonstrated. A flourishing canning establishment was running to full capacity, and what appeared to be satisfactory contracts were entered into by the homesteaders for the disposal of their fruit. The unprecedented rains of 1914 proved disastrous to a large part of the crop, and the slump in prices (due to the troubled conditions in Europe, together with the general overproduction from new acreages) brought home in a striking manner the uncertainties of a single-crop system. The older pineapple growers had already found that successive plantings of pineapples on the same ground invariably give declining yields, regardless of fertilization and any reasonable period of fallow thus far practiced. The demonstration farm at Haiku, Maui, has under way as one of its most important projects the working out of a cropping system, which shall consist of a rotation of crops that will be beneficial to the land and of immediate cash value as well. Fortunately three or four out of the many leguminous crops already tested out on a field scale are promising for use in rotation with pineapples, which crop, it is generally believed, will remain a staple in the locality in question.

MISCELLANEOUS DEMONSTRATIONS.

Next in importance to the work of general organization of the newly created extension division is the practical farm demonstration and cooperative marketing work recently inaugurated on the island of Maui, which is to be extended as rapidly as possible to all the islands of the group.

The principal farm demonstration work on Maui is being centered on two homestead units in the Kuiaha-Pauwela tract near Haiku. The main work in cooperative marketing which has been carried on in the Kula district is also being centralized at Haiku. The work has recently been broadened to include the whole of Maui, and the other islands of the group will be given attention as rapidly as the limited means at hand will permit.

In addition to the experimental and demonstration work being carried on at the demonstration farms in the Kuiaha-Pauwela homestead tract, four extensive cooperative experiments and demonstrations and a number of minor trials are now under way on the island of Maui. A number of additional projects have been planned for the coming fall months, chiefly in the Haiku and Kula districts of Maui.

At Kula a farmers' cooperative marketing association, with a membership of over 100, has been organized and considerable farm produce marketed through it.

On both the farming and marketing phases of the extension work, as well as on the educational side, many difficult and complex problems are offered for solution. It will be especially difficult here, as elsewhere, to organize the farmers for cooperative action. The average farmer of the islands is not a business man and has not yet learned the economy and efficiency to be derived from cooperating with his neighbors. The more popular publications of the United States Department of Agriculture have been given a wide circulation among the farmers of the Territory.

One of the most important undertakings that has been imposed upon the extension division is the working out, into practical demonstrations, of efficient cropping systems whereby the fertility of the lands now being devoted to pineapple growing may at least be maintained if not improved. A permanent agriculture can not be built up under the present systems of crop and soil management as practiced even by the most advanced pineapple growers. The customary successive plantings of pineapples on the same land have invariably produced diminishing yields, even when the land has been left to lie fallow for a number of years between plantings. While a few desultory attempts have been made at green manuring pineapple lands, no systematic experiments in practical crop rotations and green manuring have been recorded. There appears to be no valid reason why the well-established principles of soil management, as they apply to other crops, should not be applicable to pineapple culture. It will be the aim of the extension division to make practical applications of many of the improved methods worked out by the

Hawaii Experiment Station, which, because of lack of practical demonstration, have not been brought home to the farmers with sufficient force to induce their adoption.

Real extension work in agriculture can not long ignore agricultural education. Such education and training has only as yet been hinted at in Hawaii, while on the mainland this important phase of extension work is receiving most careful study. The majority of rural inhabitants can not attend agricultural high schools and colleges. For these the best possible educational advantages should be brought to the farms and homes.

DEMONSTRATION FARMS.

The main farm demonstration work on Maui is being centralized on two homestead units situated in the Kuiaha-Pauwela tract near Haiku. The two farms are representative of average conditions in the lower and middle section of the homestead tract and apparently of a large part of Maui.

The lower homestead is in the drier section of the Makawao region. The average rainfall is about 40 inches per annum. Climatically this section appears to be well adapted to diversified and intensive agriculture. This particular homestead was among the first to be settled upon, the original settler planting his first crop of pineapples in 1911. An excellent crop of fruit was harvested in 1913, but in the succeeding year many of the plants sickened, and the yield of fruit was greatly reduced in consequence. Owing to financial difficulties, the original settler abandoned the farm in the fall of 1914. It was taken over by the superintendent of extension for demonstration purposes in January, 1915. The crop for 1915, both from old and new plantings, was practically negligible. In the sheltered portions of the farm fine vegetables in considerable quantity were grown. Both bananas and papayas, though now growing without care, are of excellent quality. The pineapple fields, consisting of about 10 acres, were abandoned to weeds, as it was considered hopeless to restore them to profitable production. However, about 50 tons of pineapples weighing a little under 3 pounds each was produced.

Immediately upon taking possession of the lower homestead, a tract of 16 acres was cleared of brush, the main growth being heavy grass sod and young guava which had sprung up after $1\frac{1}{2}$ years of abandonment. The land was then given 3 plowings, 6 disk harrowings, and 2 draggings at a cost of $40 per acre for the tillage operations. This cost is on a basis of $6 per day for a man, 3 good working mules, and implements. The first crops were planted on May 6 and the last on May 28, 1915. The following crops have been planted for demonstration purposes.

FIG. 1.—BEANS AND CORN INTERCROPPED, PINEAPPLES IN BACKGROUND, HAIKU DEMONSTRATION FARM.

FIG. 2.—PREPARING GROUND IN PINEAPPLE FIELD FOR DYNAMITING, HAIKU DEMONSTRATION FARM.

FIG. 1.—DETAILED VIEW OF HONOHONO, A VALUABLE SOILING CROP FOR DAIRY CATTLE, GLENWOOD SUBSTATION.

FIG. 2.—SILO AND GENERAL VIEW OF THE GROUNDS OF THE GLENWOOD SUBSTATION.

Crops grown on the lower demonstration farm.

Crops.	Number of varieties.	Method of culture.
Field corn and beans	4 each.	Intercropped.
Jack beans for seed	1	In rows 2½ and 5 feet apart.
Sunn hemp	1	In rows 2½ feet apart, 25 and 50 pounds seed per acre.
Soy beans	4	Inoculated and not inoculated.
Pineapples	1	Ordinary.
Do	1	To be plowed under and green manured.
Paragrass	1	Broadcast.

The middle demonstration farm is a well-established homestead. The equipment in farm buildings, farm machinery, implements, work animals, etc., is among the best in the Kuiaha-Pauwela and Kuiaha-Kaupakuhua homestead tracts which surround it. Systematic plantings have been made each year since the homestead was settled in May, 1912. While the main crop has been pineapples, for which the lands are especially well adapted, a cropping scheme is in operation which includes a definite rotation system. The crops employed are shown in the following table:

Crops grown on the middle demonstration farm.

Crops.	Number of varieties.	Crops.	Number of varieties.
Pineapples, 1, 2, and 3 years old	1	Peanuts	4
Corn	2	Watermelon	4
Legumes	4	Artichokes	1
Potatoes	8	Field beans	2
Sweet potatoes	3	Forage grass	2

The young pineapple plantings are being subjected to intercroppings of dwarf field beans, as are also some of the plantings of corn. (See Pl. V, fig. 1.) The success of this demonstration has introduced the practice among a number of local pineapple growers. A series of fertilizer, tillage, and dynamiting experiments with pineapples is also under way. (See Pl. V, fig. 2.) All crops grown are under fertilizer, liming, and tillage experiments. Careful records are being kept of all farm operations, and it is expected that these data will prove valuable to prospective homesteaders.

COOPERATIVE EXPERIMENTS.

In April, 1915, a 6-acre, cooperative, green-manuring, and legume-rotation experiment with pineapples was entered into with the Haiku Fruit & Packing Co. A project was worked out whereby the influence

of green manuring and rotation over a period of five years can be determined. Four leguminous crops are under test. The company furnishes the land, labor, and seed, while the extension division gives general supervision when such becomes necessary. The work is being unusually well done by the company and valuable results are expected.

A private planter has requested the services of the extension division in carrying on cooperative experiments in dynamiting and in treating soils antiseptically in pineapple culture, the land, labor, and materials all being supplied by the owner, who is one of the most advanced planters in the district. Another pineapple planter, who is entering into the dairy business, is undertaking a cooperative forage-crop and pasture-grass experiment. Largely through the suggestion of the extension division, this same farmer has acquired a herd of pure-bred Jersey cattle.

Early in the spring, through the advice of the extension division, an acre of beans was planted by each of some 20 homesteaders and others. The crops from all these tracts have been harvested and nearly all have been thrashed and marketed. It is hoped that bean culture may in time become as important an industry in this region as it already is in Kula.

Fifty pounds of Sudan grass has been distributed in the district, mostly in 1 and 2 pound lots, for trial and report. One grower reports that but for his half-acre patch of Sudan grass he would have suffered materially for forage for his dairy herd.

Four different projects have been planned and three are under way for cooperative leguminous crop demonstrations. These will be located along the main road running through the Kuiaha-Pauwela homestead tract. The value of these legumes has already been demonstrated on the extension division farms. The most promising kinds are jack beans, velvet beans, sunn hemp, and cowpeas. These are valuable for green manuring and forage, as well as for their seed which is now beginning to be eagerly sought by the sugar plantations.

The cooperation of the Territorial office of public lands and the division of forestry has been secured, and it is hoped that newly opened homestead tracts throughout the islands may hereafter have at the outset whatever assistance the extension division may have to offer.

In the newly surveyed Makawao homestead, which is shortly to be opened for settlement, a homestead unit is to be set aside for agricultural demonstration under the supervision of the extension division. It is also planned to reserve wide tree belts as a protection against the excessive winds that prevail there. Mr. C. S. Judd, chief forester of the Territory, is to give this matter his personal attention.

REPORT OF THE GLENWOOD SUBSTATION.

By F. A. Clowes.

During the year the work of the substation has been continued along lines similar to those indicated in previous reports. The most interesting features of the crop work are the use and value of honohono for a soiling crop, *Paspalum dilatatum* for pasture, and cane tops for silage. Excellent results have been secured with chicks kept according to approved methods, and a flock of 250 pullets has been raised and housed in colony houses designed from standard plans, but altered slightly to suit local conditions. Considerable extension work has been carried on with excellent results.

HONOHONO (*Commelina nudiflora*).

From May 1, 1914, till April 30, 1915, the yield of honohono from a plat 10 feet square, which was a representative part of the field, was weighed at each cutting. The total yield of green feed per acre, calculated from this plat, was 223.6 tons (Pl. VI, fig. 1).

Honohono is an extremely succulent feed, much relished by cattle. Cattle fatten and produce an abundance of milk when pastured where it is plentiful. A study of the records of one of the pioneer dairymen at Glenwood shows that during a 29-month period, at a time when honohono was abundant, his herd of 33 cows of mixed breed gave an average annual milk flow of 6,100 pounds of milk per cow. The highest 12-month record was 8,616 pounds, and the lowest was 3,092 pounds. One dairyman in the same region secured a yield of 11,000 pounds from a Holstein cow fed honohono. It is believed that the yield of green feed recorded at the substation is not exceptional. Calculated from analyses reported by the station,[1] a ton of green alfalfa would contain the same amount of protein as 4.7 tons of honohono. Looked at in another way, 223.6 tons of honohono, the yield of 1 acre, would contain the same amount of protein as 47.6 tons of green alfalfa, which would be considered an exceptional yield from an acre in one year. For the food constituents other than protein, the comparison is even more favorable to honohono. To cultivate honohono, an abundant supply of manure

[1] Hawaii Sta. Bul. 13 (1906).

is necessary. This would be readily available were adequate provision made for the stabling of the cattle, as suggested elsewhere in this report. The cultivation of honohono as a soiling crop is proving very satisfactory in this region.

PASPALUM DILATATUM AS A PASTURE GRASS.

As a pasture grass, *Paspalum dilatatum* has given excellent results. Its strong deep root system enables it to withstand the tramping of stock in wet weather better than any other grass tested at Glenwood that is equally relished by the cattle. It has been extensively planted by local dairymen since its introduction by the substation. Both seed and divided roots have been used for planting. Homesteaders have been supplied liberally with roots from the fields of the substation.

CANE-TOP SILAGE.

The silo (see Pl. VI, fig. 2) was filled during June and July, 1914, with cane tops from neighboring fields. The weather during these months was excessively wet. The roof was not put on the silo till filling was almost completed, and as a consequence, much water found its way into the silo. The cane tops were bundled in the field and loaded on cane cars on the portable track used by the Olaa Sugar Co. in getting out the cane. The cars when loaded were hauled to a convenient place, and the tops were transferred to a wagon and hauled to the silo. Owing to various unavoidable interruptions, the silo filling was greatly delayed, and the silage was expensive. Some of the cane tops were cut two weeks before they were put into the silo. Notwithstanding the resulting staleness and the excessive amounts of water that went into the silo during filling, the silage was of fair quality and was eaten readily by the cattle and horses. To adapt the silo to profitable use for cane tops, it should be so located that there will be a minimum amount of labor in getting the cane tops into the silo. Since the economical use of the manure is a factor of controlling importance in any scheme for the use of considerable quantities of cane tops, the location of the silo and the feeding yard should be such that the manure can be supplied to the fields without too long a haul. The yield of cane tops per acre is about 10 per cent of the weight of the usable cane. On the unirrigated plantations this by-produce would run from 4 to 8 tons of cane tops per acre. These amounts are equivalent to about half the yield of corn silage secured by the live-stock farmers. A comparison of analyses of corn silage and cane-top silage indicates that the cane-top silage and corn silage are probably not greatly dissimilar in feeding value. This being so, it only remains to develop satisfactory practical

methods to produce, on every acre of cane land, a crop of beef, milk, or butter as a by-product of the sugar industry. This would ordinarily be equal to one-half of the main crop of the live-stock farmer elsewhere. In the feeding of silage to secure economical returns, supplementary grain feeding appears to be necessary. With judicious care of the manure, the fertilizing elements secured through the use of these grain feeds would replace much of the commercial fertilizer at present imported.

CATTLE.

During the year the station loaned the herd bull, Raymond of Alta Vista, to the Board of Commissioners of Agriculture and Forestry for four months, and he was placed by them at the Hilo Quarantine Station, where 15 cows were brought to him for service. This arrangement distributed his service over a large area without inconveniencing the Glenwood homesteaders to any extent.

The herd now consists of 1 registered Guernsey bull and 3 registered Guernsey cows, 1 registered yearling heifer, 2 registered heifer calves, and 2 unregistered Jersey cows. To adequately demonstrate the best methods of caring for cattle, the herd should be increased to 10 or 15 milking cows. Funds are not at present available for this purpose.

In the earlier part of the year, just previous to calving, one of the Guernsey cows, Kitchener's Vimera, was much troubled with sore feet, which, with the exposure to the heavy rains and the strain incident to parturition, kept her in very poor condition for several months. During wet seasons like the summer of 1914, the feet of cattle at pasture develop raw sores in the flesh between the divisions of the hoof. The horn on the inner surface of the hoof also becomes pitted and decayed, and the toes become sore. The horn of the hoof sometimes becomes much elongated, commonly reaching a foot in length unless trimmed. This lengthening is due to the absence of hard ground, which would ordinarily wear off the natural growth of hoof. The weight is then thrown back upon the rear of the hoof, thus adding to the other discomforts. Unless given attention, cows become so lame that they are unable to graze over a sufficient area while at pasture to keep them in good condition. By trimming off the surplus horn, by washing between the claws and applying antiseptics, and by keeping the animals out of the mud, cures are easily effected. Three of the cattle at the substation developed these troubles in the earlier part of the year before an extension of the stable made it possible to shelter all the stock.

When any considerable number of animals is affected their care becomes a serious burden unless adequate stabling is available to per-

mit of the animals resting on dry ground during heavy rains and at feeding times. The heavy rains, even when they do not cause sore feet, affect adversely the condition of the cattle, no matter how much they are fed, unless they can have adequate protection. On account of these facts outlay for stables and covered yards can be made a profitable investment. The value of the manure saved by providing concrete floors in these shelters would eventually repay the cost of the concrete construction. In July the station stable was extended to provide cover for all the stock.

FARMING OPERATIONS.

Throughout the whole region on the windward side of Hawaii and Maui the weather was so wet from the first of April to the end of September, 1914, that field work, with the exception of the unavoidable cane harvesting, was at a standstill. At the end of September, when the weather was comparatively clear and cultivation was possible, the fields were quickly restored to good condition, and little injury resulted to growing crops. In the cane fields effective results were obtained in weed control by the use of arsenite of soda on the dense growth. This destroyed at one spraying stands of weeds that would have taken several cultivations to subdue. At the substation no advantage could be taken of the good planting weather in the fall, since funds for the pay of labor were not available on account of the curtailment of the Territorial allotments. On this account no plantings were made from April, 1914, until April, 1915. Seasons such as that of 1914 occur only occasionally and do not prevent farming operations where the operators are not hampered by adverse circumstances other than the weather. Their occurrence does, however, point to the necessity of placing chief reliance on perennial crops such as the pasture grasses, Para grass, honohono, sugar cane, sorghum, and others that will undoubtedly come into favor with the greater use of cultivated crops in connection with the live-stock industry.

POULTRY.

The greatest drawback to poultry culture in Hawaii is the prevalence of a number of contagious diseases. Probably the most troublesome of these is sorehead.[1] It is very destructive to young chicks, but not to mature fowls. The method by which this disease is carried from fowl to fowl is not definitely known. Mosquitoes and insect parasites probably play an important part. The disease is most prevalent during the warm months from May to September. It has been the experience of many that early hatched chicks either escape

[1] Hawaii Sta. Press Bul. 46 (1914).

the disease altogether or recover from the attack. Incubator-hatched chicks, brooded artificially and kept from contact with other fowls, are less frequently affected than chickens brooded under hens. Chicks kept off the wet ground and properly cared for under cover till 6 or 8 weeks old are less frequently affected than those allowed on the ground at an earlier age. Well-fed chicks, given abundant exercise, are likewise less frequently troubled than neglected chicks.

There has been no contagious sickness among the birds at the substation. This is attributed to the fact that care has been taken to prevent contact with other birds. The houses are disinfected regularly, and the chicks are hatched early in the season. At the close of the breeding season in 1914 and before any of the chicks were put out of the chick pens, the breeding flock was disposed of, and the chicken houses were thoroughly cleaned and disinfected before placing the chicks in them. With the exception of three male birds, purchased for breeding purposes, the entire flock has been hatched in incubators and raised on the place, free from contact with other fowls. The roosts and dropping boards have been sprayed bimonthly with a mixture of 4 parts crude oil, 2 parts kerosene, and 1 part creolin. The houses are thoroughly cleaned annually and sprayed inside and out with the above mixture. As a result the birds have not been troubled with lice and mites, which in large measure explains the absence of disease. At the commencement of the fiscal year there were in the station flock 38 White Leghorn pullets and 12 Rhode Island Red pullets. One Rhode Island Red pullet was killed for examination. She was apparently healthy and fat but laid no eggs, although she entered the trap nest regularly. A post-morten examination showed that the abdominal cavity was filled with soft-shelled eggs, flattened out, and occupying all the space not filled with the intestines and other abdominal organs.

Throughout the year the flock was fed on commercial scratch feed scattered in the litter during the day and in a hopper just before night. The total consumption by the flock for the 12 months was 1,800 pounds, which cost $45, or 36 pounds per bird at a cost of 90 cents per bird. As the birds had free range, they picked up a large part of their living. During the year 4,204 eggs were produced. Part of the feed cost should be correctly chargeable to increase in the weight of the birds, but charging it all to the eggs, the cost per egg for the grain feed was 1.07 cents. The average wholesale price of eggs in Honolulu was about 43.5 cents per dozen, from which must be deducted the freight and marketing charges of about 5 cents per dozen.

Colony houses of four designs have been erected to determine their relative suitability. The design that seems most satisfactory is of the

shed-roofed type, 10 feet square, built of surfaced, tongued, and grooved northwest fir, with ceiling over the roosts for ventilation, built-in dry mash hopper, roosts for 50 birds, and 15 trap nests. The cost of each house was $60. Allowing for 5 per cent depreciation and 5 per cent interest on the investment, the cost of housing per bird would be 12 cents per year.

EXTENSION WORK.

Through the month of July the superintendent of the substation was instructor in agriculture at the summer school for teachers under the auspices of the department of public instruction.

Through the suggestion of the substation, the cooperation of a number of civic organizations was secured for the holding of the first Hawaii County Fair at Hilo. The superintendent of the substation was the chairman of the managing committee of this fair. Great success met the effort expended in this attempt, and the fair is assured as an annual event. It has done much already to stimulate interest in poultry culture and the breeding of better live stock. Its influence on other branches of agricultural production is also considerable.

The boys of the Glenwood School have been given weekly instruction in milk testing at the schoolhouse and later at the substation. The work is now developing along the lines of cow-testing associations. The boys range in age from 8 to 15 years. The parents of each boy are directly engaged in butter making. The boys are much interested in the work and the accuracy of their testing is surprising.

The substation cooperated with the Hilo High School in the operation of a hatchery, and aided in the agricultural work by giving suggestions and advice. The substation supplied the hatchery with 100 dozen eggs for hatching, and loaned one incubator at the close of the season's hatching at the substation. Through the Hilo High School hatchery over 3,000 pure-bred, day-old chicks have been distributed. Where it was acceptable to the purchaser, advice was given as to the care of the chicks. This advice was naturally more frequently sought by school pupils than by adults. The system of care and feeding advocated was that outlined above as in use at the substation.

In every case where this system has been followed excellent results have been secured. Two cases of sorehead epidemic occurred among the chicks that had been distributed from the High School hatchery, but in both of these cases the chicks had been kept on the ground, contrary to the advice given. Sorehead was very prevalent in the town of Hilo during the months of April, May, and June, 1915. It is noteworthy that no cases occurred among the chicks sold from the hatchery and raised under cover and otherwise cared for according to

directions, including the feeding of dry mash and green feed from hoppers and scratch feed in deep litter. Poultry culture has been greatly stimulated by these efforts.

In recent years the methods of field cultivation on many of the sugar plantations have been greatly changed. At one time most of the field work was done by large gangs of coolies under the supervision of overseers. Gradually this method is being superseded in the interest of efficiency by cutting up the fields into smaller areas, which are leased to small planters.

Most of the plantations near Hilo plan to retain for cultivation by hired labor only sufficient land to profitably employ their labor force during the time the mill is not grinding. A great deal of the homesteading of the public lands has been done by citizens whose training has not been along the line of farming. Where the homesteads have not been sold shortly after being deeded to the homesteader, they are usually rented to the class of tenants that are leasing the lands of the large plantations. There has, therefore, developed a large class of tenant cane growers and a rural social problem, similar to that presented by farm tenancy elsewhere, but complicated by the one-crop system and the fact that the largest landlords, the plantation corporations, also control the cane market of the tenant.

These people, the homesteading landlords and homestead cane growers, have repeatedly appealed to the station for advice and assistance. This work did not fall directly within the scope of the station work, but such assistance has been rendered as seemed to be in accord with the general policy of the department.

HORTICULTURAL OBSERVATIONS IN PORTO RICO, CUBA, AND FLORIDA IN RELATION TO THE HORTICULTURE OF HAWAII.

By J. Edgar Higgins.

In June, 1914, when the writer was about to close a year's leave of absence, instructions were received to report for duty in Porto Rico and proceed to Honolulu via Cuba and Florida, making observations of tropical horticulture en route. Considerable attention had already been given to the fruit industries of Porto Rico, and, after a week or more of further investigation, the steamer was taken, on June 29, direct to Havana. No attempt at an exhaustive study could be made, but much valuable comparative information was obtained, a part of which is recorded herewith, and much of which is on record for reference when required.

THE PINEAPPLE INDUSTRY IN PORTO RICO.

The pineaple industry of Porto Rico occupied during the year 1912 an area of 3,654 acres.[1] The output was valued at $943,445, of which $258,671 represents the value of the canned product and $684,774 the value of the fresh fruit. Thus, less than 28 per cent of the total value of the crop was received for the canned product. The canning of pineapples, however, has been on the increase steadily, but has not increased so rapidly as has the export of fresh fruit, which in 1914 was valued at $1,245,215. The proximity to great markets and comparatively frequent opportunities for shipping account for the more rapid development of the fresh-fruit industry. Steamers ply frequently between the island and New York.

The organization of the industry is quite different from that in Hawaii. There are practically no large corporations in Porto Rico. For the most part the holdings are small as compared with those of Hawaii. There are probably few, if any, individual or corporate holdings in excess of 250 acres. Pineapples are grown almost exclusively by Americans on farms or plantations. There are thus a good many growers interested in the business, but they are very widely separated, being scattered throughout the greater portion of the northern side and the western end of the island.

[1] War Dept. [U. S.], Ann. Rpt. Governor P. R., 12 (1912), p. 135.

CULTURAL METHODS.

As has already been indicated, the pineapple plantations are located chiefly along the northern side and western end of the island. These are all at comparatively low elevations, many being only slightly above sea level and none above a few hundred feet. They are nearly all served by the railroad which extends around the western end of the island from Ponce on the south to many miles east of San Juan on the north.

The soils on which pineapples are grown in Porto Rico are of several types, the sandy and sandy loam predominating along the northern side of the island, with some gravelly loam. Some clay loam, particularly on the western end, is devoted to the industry, and it resembles in appearance much of the pineapple soil of Hawaii. Some indications of manganese are found, but manganese does not appear to have given rise to much difficulty. Drainage is as vital a problem in Porto Rico as in Hawaii. Even the sandy soils are in many cases underlaid by a more or less impervious stratum which makes drainage difficult, particularly on lands with very slight grade.

Propagation methods do not differ materially from those in Hawaii, except that crowns are seldom if ever used. Slips and suckers are used almost entirely. With these is to be included the underground sucker which in Porto Rico is called a ratoon. Perhaps the reasons for the disuse of crowns are that the Red Spanish variety, which is the one most commonly grown, produces suckers abundantly; that these suckers produce fruit much more quickly than the crowns, and, further, that the Cabezona, which is the only other variety of importance, is extremely slow in producing a crop from crowns.

In preparation of the soil a long period of tillage is found necessary, as in Hawaii. The ridge system of planting is much in use, probably because it aids in quickly removing excessive water from the plants in a country where torrential rains are common. Flat planting, however, is seen in many places. About 12,000 to 14,000 plants per acre are set in case of Red Spanish, and various forms of arrangement are employed, some plantings being made as close as 12 by 12 inches in the beds or double rows. Much of the planting is done in the winter, the season of heavy cropping coming in the spring. Some progressive planters have found it possible and advisable to plant in July and thus distribute the season of cropping over a larger portion of the year, getting perhaps 75 per cent of the crop out of season or when there are few pineapples on the market and prices are good.

Pineapples are much used as an intercrop with citrus trees, and this combination, if carefully and wisely handled, sometimes results

in the pineapples practically paying for the establishment of the citrus orchard (Pl. VII, fig. 1). About two ratoon crops are generally taken whether the pineapples are grown exclusively or as an intercrop. Replanting does not usually follow immediately after the destruction of the first planting. It has been found necessary in Porto Rico, as in Hawaii, to prepare the land very thoroughly before the second planting. Where it is possible, fallowing for a year or more is frequently practiced, the land being used for pasture. In the destruction of the old plants, the ever-present machete is very much in evidence. This swordlike tool, which is used by the natives for almost every conceivable purpose in gardening, is very effective in cutting down the old plants. If the growth is dry enough after weeds have been allowed to grow it is sometimes burned over.

The cost of production of pineapples in Porto Rico is apparently about the same as in Hawaii. Pineapple lands, unplanted, cost from $75 to $250, the price being determined to a large extent by location. Labor can be secured at 62 cents per day, but because of the larger proportion of handwork and possibly lower efficiency, the planter's labor bill is probably not less in Port Rico than in Hawaii. The yield of pineapples ranges from 10 to 14 tons per acre. Fertilizers are used rather freely and with profit to the grower.

The varieties of most importance have already been mentioned. It is estimated that probably 90 per cent of the crop is Red Spanish. This variety is known to most growers in the Territory of Hawaii, although it has never proved popular here except in the Kona district of the Island of Hawaii. It is a vigorous grower and yields freely. The fruits are of small size, ranging from $1\frac{1}{2}$ to $4\frac{1}{2}$ pounds. They are of good quality, ship excellently, and sell well on the market. They are better adapted to fresh-fruit trade than to canning, because of their small size, which makes it impossible to get a large percentage of slices of sufficient diameter to pack the highest grade of canned fruit. They are, however, much used in canning. The Cabezona is an extremely large fruit, averaging from 8 to 10 pounds, 15 pounds being not uncommon, while fruits weighing 18 to 25 pounds have been reported. This variety has been grown in one locality in Porto Rico since the early part of the nineteenth century and has come to be known in some other parts of the world as the variety Porto Rico. Its origin in the island is not known. It seems well adapted to local conditions, particularly on the loamy soils, and is planted in those parts of the island where canning is being chiefly practiced, since it is not well adapted to the fresh-fruit trade. The Smooth Cayenne variety, upon which the Hawaiian industry is based, is almost never grown in Porto Rico. Many other varieties have been introduced, including the hybrids originated by the United

States Department of Agriculture, but up to the present time none have proved popular for commercial cultivation except the two named above.

DISEASES AND INSECTS.

The diseases of the pineapple in Porto Rico are not materially different from those of Hawaii. Soft rot, due to the fungus *Thielaviopsis paradoxa*, is more or less destructive to fruits in transit, but the Red Spanish variety shows considerable resistance, and by proper care in curing, packing, and transportation this trouble can be rendered unimportant. Base rot, due to the same fungus, is somewhat in evidence, but in the warm soils, if drainage is provided, it does not cause much loss. Leaf spot, also due to this fungus, is found chiefly in the coolest part of the year and in wet weather. Sun scald, following the bending over of the fruit, occurs as in Hawaii, but because of the small size of the fruits and the close planting, the loss is small in the Red Spanish variety. The practice has been followed to some extent of covering these exposed fruits with a little dried grass, the work being performed by children. Pineapple wilt occurs, but usually only where the conditions are unfavorable.

Perhaps the chief insect enemy of the pineapple in Porto Rico is the mealy bug (*Pseudococcus bromeliæ*) which is so common in Hawaii. It is accompanied by ants, which aid in its distribution. When the necessity arises, this insect is held in check by means of sprays. The pineapple scale (*Diaspis bromeliæ*) was not seen by the writer in Porto Rico and was said not to occur in the island.

MARKETING.

The fresh-fruit trade in pineapples from Porto Rico is exclusively with New York as a distributing center, except for a few small shipments which may go to New Orleans. The fruits are shipped in the Florida or Red Spanish crate. The dimensions of this are $10\frac{1}{2}$ by $12\frac{1}{2}$ inches inside measurement and 36 inches long outside. This crate is well suited to the Red Spanish variety. It contains from 70 to 75 pounds of fruit, net weight, averaging about 72 pounds. There are from 14 to 60 fruits in a crate. There are few that run so large as 14's, and very few so small as 60's are shipped. The sizes and approximate corresponding weights are indicated in the table on page 63. The prices received for the fruit of late years have averaged about $2.50 per crate for the sizes ordinarily shipped—that is, from 42's up.

Until 1910 the prices received were very much lower. Up to that time there was no thorough organization of the fresh-fruit trade.

Fruits were shipped by individuals on consignment, and the results were about as unsatisfactory as those generally brought about by this system. At that time the Porto Rico Fruit Exchange was organized, at first having a severe struggle for existence, but now being well established. This is an organization of growers. At first stock was sold to nongrowers, but at the present time a man must be a bona fide grower to secure stock. Each share bears one vote in the control of the organization, and no grower can now buy more than five shares. This organization now ships about 60 per cent of the fruit grown in Porto Rico for export. It is estimated that about 85 per cent of the growers are members of the organization, but because of the heavy shipments of a few comparatively large growers, who ship independently, less than 85 per cent of the fruit is controlled by the organization. The shipping of these larger growers, however, is organized on a business basis, so that it does not demoralize the market as is always done by a large number of small growers shipping to a distant market without organization. The exchange handles about $600,000 worth of pineapples and citrus fruits per year, which is the product of between 200 and 250 shippers. Most of these shippers represent individuals or companies. There are only one or two local exchanges. The Porto Rico Fruit Exchange employs a representative to look after the shipping of its fruit in San Juan, and a dock superintendent in its employ receives the fruit in New York, examines it, and if necessary has it repacked. An office is also maintained near the fruit auction rooms in New York City. To these auction rooms samples of each brand in the shipments are taken, and from these samples the whole shipment is sold. Steamship companies segregate all brands, sizes, etc., on the wharf where the buyer takes charge of his fruit. By this system of organized marketing the fruit growers of Porto Rico have been able to bring up the standard of their pack, to purchase in large quantities packing material and fertilizers, and to raise the price from a point that barely covered the cost of production to a standard that makes a good profit in the industry.

CANNED PINEAPPLES.

There are about half a dozen or more plants engaged in the canning of pineapples in Porto Rico (Pl. VIII, fig. 1). Those at the western end of the island are putting up the Cabezona variety, which is being grown for canning purposes. They also can the Red Spanish, but this variety is put up chiefly near San Juan. The style of pack is somewhat different from that of Hawaii. Some of the canneries make

a specialty of fruit for confectioners' trade. For this purpose the pineapples are gathered before they are thoroughly ripe, and while the fruit is quite white in color. Some of it is put up without sirup. The small size of the Red Spanish, especially as the best of the fruit is likely to be shipped fresh, makes it impossible to put up a large percentage of the pack in the highest grade of sliced fruit. Many of the quite small fruits are used to put up crushed, grated, pie-grated, and other forms.

The prices which it is necessary to pay for fresh fruit are much higher than in Hawaii. The success of the fresh-fruit trade brings about this condition of affairs. The table below indicates the prices paid and the classification of the fruits.

Classification and prices paid in Porto Rico for Red Spanish pineapples for canning.

Size.	Approximate weight per fruit.	Range in price per ton.	
		1913	1914
	Pounds.		
14's	5.1		
18's	4	$20 to $25	$24 to $31
24's	3		
30's	2.4		
36's	2	10	12 to 15
42's	1.7		
48's	1.5	5	5 to 10
54's	1.3		
60's	1.2		

In some canning establishments a somewhat different method of classification has been followed, and in some instances fruits weighing less than 1.5 pounds are not accepted.

It will be seen that 30's, or fruits weighing 2.4 pounds each, are accepted as first grade, while 36's, 42's, and sometimes 48's go as second grade. Some of the canneries will accept 60's, or fruits weighing only 1.2 pounds each, at a reduced price. It will be noted that for the first grade of fruit in 1914 the prices paid were from $24 to $31 per ton. In some cases this fruit was delivered at the cannery and in other instances to the railroad, the buyer paying the freight. The second grade sold for from $12 to $15 per ton. These prices were considerably in advance of those of 1913, when first grade sold for $20 to $25 and second grade for $10. In some instances all fruit from 48's to 14's was taken in 1913 at a uniform price of $22 per ton.

It will be noted that these prices are higher than any that have been paid in the history of the canning industry in Hawaii, and they exhibit a strong upward tendency simultaneously with the complete demoralization of prices on fresh pineapples in Hawaii, where they

sold as low as $5 per ton for first-grade fruit. No attempt is made here to explain this wide divergence in prices of raw material. The canned product from Porto Rico sells (at retail) at somewhat lower prices than that from Hawaii.

PINEAPPLES IN CUBA.

Cuba ships about a million and a quarter crates of pineapples per year, the size of the crate being the same as that used in Porto Rico. A striking contrast between the Porto Rican and Cuban industry lies in the fact that there are many small growers of pineapples among the Cubans themselves. The cultural methods are similar to those pursued in Porto Rico, and the soils likewise vary from sandy to loam. The Red Spanish is the predominating variety, but a few Cayenne are shipped, chiefly from the Isle of Pines. The Abachi (Abakka) is frequently found in the home markets and is popular because of its fine flavor and texture, as well as its attractive appearance. This is a conical-shaped fruit and has the striking character of ripening before the fruit has turned yellow. If kept, however, a very fine color appears before the fruit has become too ripe for use. This variety sells in the Havana market at higher prices than the Red Spanish.

Practically all the Cuban crop is shipped as fresh fruit except the portion which is so consumed at home. There is very little organization of the pineapple growers for marketing purposes, which results in low prices and demoralization of the markets. Much of the packing is also poorly done, without sufficient curing of the fruit or care in its handling. Fruits are often brought from the field to the packing house in bulk on large bullock carts without springs (Pl. VIII, fig. 2), which, in itself, would cause enough bruises to account for the very heavy losses which are often sustained through decay in transit.

There appear to be large possibilities for the development of the pineapple industry in Cuba. The areas of available land at comparatively low prices, the proximity to the great markets of the United States, together with the location of the island with reference to the routes of travel to Europe, all are favorable to a large development. The cost of labor is higher than in Porto Rico.

PINEAPPLES IN FLORIDA.

The output of pineapples from Florida is quite variable. It has exceeded a million crates in a single year. During 1914 it is doubtful whether the shipments amounted to more than a quarter of a million crates. This shrinkage is to be accounted for by the severe frosts of the preceding winter. Florida appears to be so well adapted to

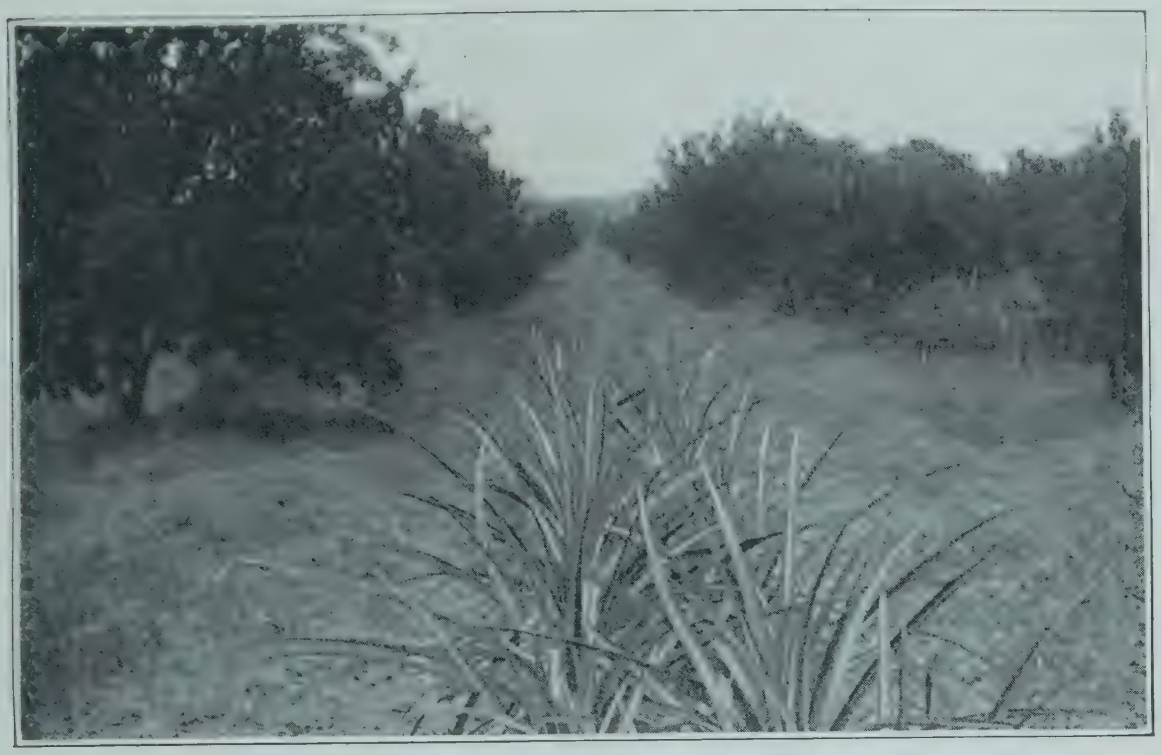

FIG. 1.—CITRUS ORCHARD WITH PINEAPPLE INTERPLANTING IN PORTO RICO.

FIG. 2.—VIEW IN A 20-ACRE AVOCADO ORCHARD IN FLORIDA.

FIG. 1.—A PINEAPPLE CANNERY NEAR SAN JUAN, PORTO RICO.

FIG. 2.—A BULLOCK WAGON DELIVERING PINEAPPLES IN BULK AT THE PACKING HOUSE IN CUBA.

other horticultural crops—such as grapefruit, oranges, and early vegetables—that the production of pineapples may not be greatly extended.

The pineapple industry of Florida is divided into comparatively small holdings, by far the larger portion of the crop being grown by individuals or small companies. Practically the entire output is shipped as fresh fruit, the canning trade being almost negligible in this State. Some of the pineapples shipped fresh from Florida, as well as from Cuba and Porto Rico, find their way into the canneries of the United States, notably in the neighborhood of Baltimore.

The pineapple area in Florida is confined chiefly to a comparatively narrow zone along the eastern coast line of the southern part of the State, centering about Fort Pierce. The soils are almost pure sand, with a small admixture of humus. These soils, when heavily fertilized, produce very fine crops of pineapples. The arrangement and spacing of plants is much the same as that described for Porto Rico. The bed system is quite frequently found.

The Red Spanish is almost the universal variety and seems well adapted to the soils and conditions of that region. The variety Abachi, mentioned above, is grown to some extent, and skillful shippers succeed in placing it safely in the northern markets, although it is much more susceptible to injury in transit than is the Red Spanish.

Among diseases and insects in Florida may be mentioned wilt and the pineapple scale and mealy bug. Wilt has been quite prevalent and has caused heavy losses. The means for controlling the mealy bug and scale are similar to those mentioned in the discussion of the Porto Rican industry. It was found that some growers were protecting their fruits from sun scald by covering them with small pieces of cotton or other rough material where they had broken over and were lying exposed to the sun.

The fruit is shipped in crates of the same size as those mentioned above and goes chiefly to the large eastern markets, but is sometimes found as far west as San Francisco. There is not the organization of pineapple growers for the marketing of the crop that is found in the case of the citrus growers of the State, who are well organized. Many of the pineapples are shipped through commercial firms in Jacksonville. Florida, although nearer the great markets, is said to have a disadvantage in freight rates, the charge, for example, being 48 cents per crate from Miami to Cincinnati, while from Havana to the same destination it is only 29 cents. The Florida fruit has a long haul by rail before it reaches the market, but it is packed and handled so much better than Cuban fruit that the profits have probably been greater in Florida than in Cuba.

SUMMARY OF OUTPUT OF FRESH PINEAPPLES IN COUNTRIES VISITED.

In round numbers the output of fresh pineapples in the countries visited may be summarized as follows:

	Crates.
Florida	600,000
Cuba	1,250,000
Porto Rico	650,000
Total	2,500,000

Estimated on a basis of 72 pounds per crate, the total crop would be about 90,000 tons. The output of Hawaii in the form of canned pineapple for 1914 was approximately 2,250,000 cases or about 90,000 tons. The fresh fruit export of Hawaii amounts to only a few thousand tons. Florida, Cuba, and Porto Rico sell as much fresh fruit as Hawaii sells in cans.

CITRUS FRUITS.

The citrus industries of Porto Rico are rapidly increasing in importance. The grapefruit has made the most rapid advance, increasing in value from a little over $7,000 in 1907 to nearly $752,000 in 1914, when it equaled the orange output and at the present rate of development will soon surpass it. Porto Rico seems to be peculiarly adapted to the growth of this fruit, the trees bearing abundantly and the fruits, when well grown, being equal in quality to any of those with which they come into competition and superior to many. The business is as yet young, and although handled in a modern manner, many advances in methods of cultivation and marketing will doubtless be made.

Oranges grow on almost every finca, or farm, where they have been planted for coffee shade or for fruit production, but have received, in many cases, little or no attention. These are the seedling oranges which are in the local markets during a large part of the year, coming first from the lowlands and later from the altura, or high country. Late in the winter these fruits become well colored and are excellent for domestic consumption. Considerable shipments of these are also made to the United States, where in seasons of high prices they bring enough to pay a small profit to the shipper. The methods of handling these oranges, however, are far from satisfactory, since the growers are wholly unfamiliar with commercial methods of culture, handling, and packing.

Probably the larger part of the oranges shipped from Porto Rico is grown in orchards and handled in as modern a manner as could be expected in the early stages of the development of the industry. These orchards, budded to commercial varieties, are owned and con-

trolled by Americans almost exclusively. The Porto Ricans themselves have not adopted this type of cultivation.

The lemon is not produced in Porto Rico to any considerable extent, although there are some trial plantings on the south side of the island. The orchards of oranges and grapefruit just referred to are along the north side of the island in much the same localities as the pineapple.

In methods of cultivation there are some other points which are worthy of notice. The use of cover crops is notably on the increase, the jack bean (*Canavali ensiformis*) having proved of great value there, as it has in Hawaii. At most seasons of the year in the citrus districts there is an abundance of rain to maintain the trees, and the cover crop, which prevents the soil from washing, adds nitrogen, and maintains the supply of humus. In some cases grass has been allowed to grow under the trees, and some growers claim that the results have been very satisfactory.

The prevailing winds necessitate permanent and effective windbreaks, and one of the striking aspects of the landscape is the windbreak of bamboo about these orchards. Under Porto Rican conditions, the bamboo lends itself well to this use, making a rather thick mass of foliage through which the wind sifts slowly.

Porto Rico appears to have a comparatively easy task in the control of scale insects which add so much to the expense of citrus culture in many parts of the world. Nearly all the common scale insects of citrus are found in the island, but most of them are held well in check by fungi. The red fungus (*Sphærostilbe coccophila*), the gray fungus (*Ophionectria coccicola*), and several species of black fungi are found to hold the scales under control. The relation of windbreaks to the control of insects by fungi is important. In exposed places, the fungi do not prosper sufficiently to be an effective means of control. The windbreaks, therefore, serve a double purpose in protecting the trees from wind injury and in assisting the warfare against insects. It is not generally found necessary to distribute these fungi by spraying or other artificial means. The attempt is being made to introduce these beneficial fungi into Hawaii. It is not to be expected that they will prove as effective in the dry climate of Honolulu, but in many humid localities, such as Hilo, Puna, and the Kona district of Hawaii, it is not improbable that these fungi would be a great aid in controlling the purple scale and the Florida red scale, which are so prevalent in these islands.

Aleyrodes howardi, related to the white fly (*A. citri*) which has given so much trouble to the citrus growers of Florida, is found in Porto Rico and is said to be a native species. It affects the orange, as well as a long list of other plants, but is not of so much economic importance, probably on account of its being parasitized by a hymenop-

terous insect not yet identified. *Pseudococcus citri* is said to be held well in control by the Australian species of ladybird (*Cryptolæmus montrouzieri*).

In Cuba the brevity of the visit made it impossible to do more than take a passing glance at the citrus development which has taken place in recent years. There are a great many small citrus holdings and a number of very large plantations of oranges and grapefruit, considerable American capital having been invested in that island. There is a large local consumption of oranges, many of these being shipped to the markets of Havana and the other large cities of the island. The larger part, however, is shipped to the United States. Because of the almost unlimited extent of land available at comparatively low prices, and because of the proximity to the American markets, there appears to be opportunity for much greater development. Many citrus orchards, however, have been planted and abandoned for one cause or another. Some of these have been on land unsuitable for their culture.

A striking feature in some of the Cuban citrus groves was the presence of grass, which has also been mentioned as having been found, but to a less degree, in Porto Rico. Many growers of citrus trees in Cuba claim that they have obtained better results by this method than by any other which has been tried. Whether a thorough test of leguminous cover crops has been made was not determined.

Scale insects are controlled by the same means as in Porto Rico. In all places visited, fumigation was never practiced, and spraying was used chiefly as a means of controlling the rust mite. This pest is very common and injures a large amount of fruit, which, although not affected in quality, is so badly injured in appearance as to seriously reduce the price. By means of the usual sprays, notably sulphur, the injury can be kept down to negligible proportions.

An orchard wagon of American manufacture seen in Cuba is worthy of mention as being possibly adapted to use in the pineapple fields of Hawaii. The peculiarity of this wagon is that the rear wheels follow exactly in the track of the front wheels. This prevents injury to many plants because not a few drivers who are able to drive well enough to get the front wheels away from the plants, run over them with the rear wheels of the ordinary wagon. Some of the pineapple growers of Hawaii are interested in further investigation of this type of wagon.

The citrus industries of Florida are older and more highly organized than those of Porto Rico and Cuba. The brief visit in this State permitted only a glance at a small part of the industry. Some of the matters which have been mentioned in connection with the citrus industries in Cuba and Porto Rico also impressed themselves

here. The efficiency of the parasitic fungi on some of the citrus scales was apparent. This, together with spraying for certain scales and for the rust mite, has resulted in very clean, bright fruit in many of the groves.

The highly organized system for the marketing of citrus fruits is worthy of special note. The Florida Citrus Exchange handles approximately 25 per cent of the output. The estimated crop for the 1914–15 season was about 7,000,000 boxes, of which the Florida Citrus Exchange probably handled from 1,500,000 to 2,000,000 boxes. This is an organization of producers and has done much to systematize marketing and bring satisfactory returns to the grower. The details of its organization can not be gone into here.

One of the most talked of subjects in citrus circles at the time of the visit was the citrus canker, a disease which had recently made its appearance in two widely separated parts of the State, one area of infestation being in the southern part, in Dade County, and the other in the extreme north, at Monticello, quite close to the Georgia line. This disease affects the foliage, the branches, and the fruits of several species of citrus, being notably a pest of the grapefruit, for the excellence of which Florida has become famous. This disease, which has also been found in most of the Gulf States where citrus is grown, appears to be very difficult of control. The energetic manner in which the growers and the Government are attempting to eradicate the disease from Florida is noteworthy. The warfare has passed from the stage of spraying and even of cutting down whole orchards to the use of an oil-burning torch especially constructed for the purpose. It was found that by the cutting down of the trees the operators themselves spread the disease. The torch is now applied without the operators coming in contact with the trees. So vigorous is the warfare that every tree that shows the slightest infection is burned to the surface of the ground. The soil also is treated in like manner. Whatever may be the outcome of the struggle, no efforts are being spared to rid the State of this serious disease.

The overhead systems of irrigation which have been installed in some citrus orchards attract attention. These have proved valuable not only as a means of supplying the trees with water but also in fighting frosts. The application of an artificial shower to the trees is a very decided protection during cold nights. Many growers feel that the system is worth all that it costs, either as a means of irrigation or protection against frosts.

Florida has been somewhat prolific in varieties of citrus fruits. A new orange, known as the Lue Gim Gong, which originated at De Land, is attracting much attention at the present time. Its special merit appears to be in its holding firm to the tree after it has

become ripe and well colored. It is said that it will hold on the tree for a year or more, enabling the grower to extend the shipping season for his fruit. It is described as "a late round orange of unusual merit."

Another of the originations of Florida now coming into some prominence is the Foster grapefruit, said to be a bud mutation from the variety Walters, which it very closely resembles in all particulars, except that the Foster has pink flesh, a new feature among the pomelos grown in the United States or the West Indies. Both of these varieties are now growing in Hawaii, and a limited supply of budwood will soon be available.

THE AVOCADO.

The avocado is claiming a place of considerable commercial importance in Florida and in California, but the West Indies do not appear to have awakened to the possibilities of profit in this unusual fruit. In Florida there are orchards of 25 to 30 acres, some of them now in bearing, while new plantings are constantly being made, particularly in the area along the east coast from Palm Beach southward (Pl. VII, fig. 2). The natural limitations of successful culture have not yet been determined, and there appears to be less tendency to emphasize the hardy varieties than in California. The avocado does not appear to be lacking in vigor and productivity in the parts of Florida referred to. This State possesses an unusual advantage in its proximity to great markets where its fruits can be placed about two days after picking, thus avoiding the need of refrigeration. The Trapp is the leading commercial variety and has many points in its favor, being in season when the markets are no longer glutted with northern fruits, and having a good form for packing and good keeping qualities. It is one of the easiest varieties to bud. The methods of budding are essentially the same as those which have been found adapted to conditions in Hawaii. In general practice, the bud is tied with only a waxed bandage which remains in place about 17 days, after which the bud is forced into growth by cutting back a few inches at the top of the stock and later removing its buds as they start into growth. There is a strong tendency to bud stocks in shingle boxes or other containers rather than in the nursery row, due in part to the Florida soils being not suited to the practice of lifting nursery plants with a ball of soil.

Porto Rico is rich in very excellent varieties of avocados, or aguacates, as they are known there and in other Spanish-speaking countries. The lack of effort to propagate by budding may be due in part to the high average of excellence among seedlings, but more probably to the fact that the commercial possibilities of this fruit

have not yet been recognized. With a three or four day service direct to New York, a season that could be made to cover nearly the entire year, varieties that need only to be sought out, standardized, and propagated by buds, and a climate in which the conditions are ideal and the danger of frost unknown, there appear to be opportunities that would appeal strongly to the enterprising fruit growers of California or Florida. The American fruit grower in Porto Rico is busy establishing his citrus and pineapple industries, which are yet young, and the native Porto Rican has not taken very enthusiastically to any line of fruit production.

Porto Rico doubtless has some varieties worthy of introduction into Hawaii, particularly choice early and late sorts to lengthen the season. This could be done at the present time by searching out the seedling trees, but when Porto Rican varieties have become standardized, it will be an easy matter to make the introductions by means of budwood which may be safely carried through the mails.

In Cuba, the price of avocados in July was a striking feature. Good-sized fruits were selling in Havana at 20 to 25 cents Spanish money,[1] and exceptionally good fruits are said to bring 10 cents each even in the height of the season. In the country districts, it was found necessary to pay 5 cents each for ordinarily good fruits in July, which, while not mid season, can not be regarded as out of season. It is said that they become quite cheap for a short time when they are most abundant.

There appears to be very little commercial culture of the avocado in Cuba, but interest in it is beginning to be aroused. The very large consumption of the fruit in Havana itself and the proximity to the American markets, with direct and frequent transportation, would seem to indicate that there are possibilities in the culture of the avocado here which will grow in importance as the fruit comes to be more widely known and used.

California is probably planting avocados more rapidly than any other country at the present time, plantings being made in different localities from San Diego to Butte County. In this State much emphasis is being placed upon hardy varieties, some of which are claimed to endure as much cold as the orange. These have been introduced chiefly from the highlands of Mexico. Some seedlings from Hawaiian stock were considered hardy under ordinary conditions, but many of these were unable to endure the severe cold of the season of 1912–13, when they were killed to the ground in the nursery.

In California budding in the open nursery is growing in favor, and in the heavier soils of this State it is possible to "ball" the trees

[1] The Spanish dollar has a purchasing power of something over 90 cents American money.

for transplanting. Many new varieties are being described and propagated, and there is considerable diversity of opinion as to which of these varieties are likely to take permanent places in the avocado culture of the State.

Concerning the insects and diseases of the avocado in the countries visited, some facts were noted. The avocado mealy bug (*Pseudococcus nipæ*) was found in a city park in Mayaguez, Porto Rico, but was not seen elsewhere, and so far as could be determined, it had not been reported in the entomological records of the island, which would make it appear to be a comparatively recent introduction. The same species was found in one of the orchards in south Florida, but elsewhere was not seen, and appeared to be unknown to avocado growers, indicating that it is probably a recent introduction in Florida also.

No avocado borer (*Xyleborus* sp.) was seen or reported in any of the countries visited. The larva of an insect, locally known in Cuba as the bagworm, is said to eat the foliage of the trees. It is not reported as a very serious pest. Red spiders appear to be generally distributed and do slight injury, as in Hawaii. A disease first affecting the roots but later involving the trunk also, was reported in Cuba and was said to be somewhat serious. It was not seen and its identity has not been learned.

THE MANGO.

The mango has been planted on a commercial scale by at least one company in Porto Rico. The trees are vigorous and some varieties bear abundantly. The problem of determining the varieties best suited to local conditions is now being worked out. These have to be selected with reference to several factors, notably, varietal resistance to the mango fruit fly and to the mango blight. The mango fly (*Anastrepha fraterculus*) is similar in habit to the Mediterranean fruit fly, with which every one in Hawaii is now familiar. Varieties show marked differences in resistance. The Sandersha, for example, which is one of the largest and finest in appearance, as well as a most prolific bearer, is also one of the most susceptible to the fly.

The mango blight (*Glœosporium mangiferæ*) is prevalent in the moister parts of Porto Rico, as in Hawaii, but some varieties are quite resistant. On the dry side of the island, with irrigation, this disease would do practically no injury.

One of the most promising varieties in Porto Rico is Amini, of East Indian origin. It very closely resembles Pirie, is said to be free from the attacks of the fly, and grafts readily on the native stock.

Piña (pineapple) is one of the so-called native varieties and is worthy of some attention. It has very little fiber, is of good flavor, and is quite resistant to the mango fly.

FIG. 1.—CRATES OF MANGOES AS THEY ARE PACKED IN FLORIDA.

Note the three different sizes of crates.

FIG. 2.—A TREE TOP-WORKED TO THE HADEN MANGO.

Hueva del Toro is one of the most common of the Porto Rican mangoes. It is of good appearance and fair flavor, but is somewhat fibrous and extremely subject to the attacks of the fly. It is very similar to the Hawaiian sweet mango.

In addition to several varieties of mangoes that have been introduced by the United States Department of Agriculture, three East Indian varieties have been introduced by the Misses Leitch, of Garrochales, who are making every effort to establish the mango on a commercial basis in Porto Rico. The varieties are known as Champaddan, Colombo Kidney, and Ceylon Horse House. The Colombo Kidney was seen and tasted and proved to be of excellent flavor and very fine texture.

A method of bark grafting the mango has been devised by the Porto Rico Experiment Station and is now being used by a number of fruit growers. This method has been found well adapted to Hawaiian conditions. (See p. 22.)

In Cuba there are a few commercial plantings of the mango and many of the East Indian varieties are being tested. Among the established forms that have long been in the islands, it is interesting to note the points of relationship to those of Hawaii. The variety known in Cuba as Manila is very similar to, if not identical with, that known in Hawaii as Pointed Chutney. It is of delicious subacid flavor and is free from fiber. The Seda is the same as that known in Hawaii as the No. 9, of which there are several forms all tending to the "S" shape and all of mild flavor and rather fibrous texture. Criollo closely resembles the variety in Hawaii known as the Double-Pointed Manila.

Florida has made substantial progress in establishing a mango industry, and small commercial shipments are being made regularly in season. (Pl. IX, fig. 1.) Budding is done in the nursery row and also in pots, and many varieties are being tested. The Mulgoba has been more generally planted than any other and is certainly a very fine mango as grown in Florida, where it acquires a good color. It is said to be a somewhat uncertain bearer, and growers are hoping for much from its seedling, the Haden, which is just now attracting attention and gives promise of being a heavier and more regular bearer (Pl. IX, fig. 2).

The establishment of the mango on a commercial basis is necessarily a slow process, but there can be no doubt of the ultimate outcome in countries adapted to its culture and able to ship the fruits to large markets. The best mangoes appeal to the average taste and are most attractive in appearance.

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Issued April 6, 1917.

HAWAII AGRICULTURAL EXPERIMENT STATION,
J. M. WESTGATE, Agronomist in Charge.

REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION.

1916.

UNDER THE SUPERVISION OF
STATES RELATIONS SERVICE,
Office of Experiment Stations,
U. S. DEPARTMENT OF AGRICULTURE.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1917

HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU.

[Under the supervision of A. C. TRUE, Director of the States Relations Service, United States Department of Agriculture.]

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LETTER OF TRANSMITTAL.

HAWAII AGRICULTURAL EXPERIMENT STATION,
Honolulu, Hawaii, July 17, 1916.

SIR: I have the honor to transmit herewith and to recommend for publication a report of the Hawaii Agricultural Experiment Station, 1916.

Respectfully,

J. M. WESTGATE,
Agronomist in Charge.

Dr. A. C. TRUE,
Director States Relations Service,
U. S. Department of Agriculture, Washington, D. C.

Publication recommended.
A. C. TRUE, *Director.*

Publication authorized.
D. F. HOUSTON,
Secretary of Agriculture.

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REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION, 1916.

SUMMARY OF INVESTIGATIONS.

By J. M. WESTGATE, *Agronomist in Charge.*

BUILDINGS AND GROUNDS.

During the year the only new building erected on the station grounds was a one-room cottage for one of the laborers, whose duties necessitated his constant presence on the station grounds. A considerable number of the laborers' quarters and two of the station residences were in such condition that rather extensive repairs were considered necessary.

The grounds available for station work were materially increased by the setting aside of a 13-acre tract on the Schofield Barracks Military Reservation for use as a forage-crop experimental tract. The land available at the central station at Honolulu is not typical of much of the grass and hay land of the islands, and it is thought that the results obtained in the new location will have a wider application than would be secured were the proposed work carried out at Honolulu.

CHANGES IN THE STAFF.

The scientific staff of the station shows a number of important changes when compared with that of the preceding year. M. O. Johnson was transferred July 25, 1915, from the chemical work of the Bureau of Animal Industry, United States Department of Agriculture, to succeed W. T. McGeorge as chemist, the latter having been transferred to the Bureau of Chemistry July 8, 1915. On March 1, 1916, Miss Alice R. Thompson was transferred to the Bureau of Chemistry for a year's special work on fruits and fruit wastes. C. W. Carpenter was added to the staff as pathologist by transfer on June 1, 1915, from the Bureau of Plant Industry. J. B. Thompson was appointed assistant agronomist July 6, 1915, to become superintendent of the Glenwood substation, succeeding F. A. Clowes, who resigned on July 1, 1915, to take charge of the agricultural department

of the Lahainaluna Boys' Industrial School, at Lahaina, Maui. On June 30, 1916, A. T. Longley, in charge of cooperative-marketing investigations and executive clerk of the station, was furloughed to the Territory of Hawaii so that he might devote his entire time to his duties as superintendent of the Territorial marketing division, which is carried on under the general supervision of this station. He was succeeded as executive clerk of the station by J. W. Love, who was transferred May 10, 1916, from the States Relations Service, Washington, D. C. On May 31, 1916, John McCoy resigned as collaborator. His place was filled by A. L. Arthur under an appointment becoming effective July 1, 1916.

ECONOMIC COLLECTIONS.

The numerous requests for identification of various plant diseases, fruits, grasses, legumes, and other forage and green manure crops have for some time indicated the need of a collection on the station grounds of the more important species and varieties. With this end in view a four-section herbarium case was purchased, and collections of native and introduced species of grasses and legumes, as well as of economic fungi, have been started. The fruit and other bulky specimens are being preserved in museum jars. It is planned to supplement the specimens with a file containing all available data concerning the species and varieties in question. Much of the preserved material will be available for displays at the local agricultural fairs, which constitute a new enterprise of great interest to the station.

COOPERATION WITH MILITARY POSTS.

The numerous military posts located in different parts of the island of Oahu have afforded considerable opportunity for cooperative work during the past year. The station has rendered active assistance in the efforts to establish suitable growth according to systematic planting plans for each of the military posts and reservations. Instead of cooperating with individual officers, the station has attempted, as far as possible, to have all requests for planting material come through a single representative of the Army, it being much more practicable for the station to respond to a single request for large supplies of material than to numerous requests for small amounts.

A second and more important activity from an economic standpoint has been the cooperative work in the establishment of locally grown forage grasses for feeding the Army horses and mules. A number of preliminary plantings have been made on the Schofield Barracks Military Reservation, where probably 1,000 acres of potential grass land is available for the production of such grasses and

other forage crops as may be shown to be adapted to the purpose. The seeds for these plantings have been largely furnished by the station, while the actual planting operations have been conducted by the Army. During the coming year it will probably be practicable for the station to do most of the planting with its own labor.

On June 10, 1916, the station received notification from the United States Army quartermaster at Schofield Barracks that the commanding officer of the Hawaiian Department had approved the setting aside of a 13-acre tract at Schofield Barracks, and that the same had been set aside for the use of the station as an experimental tract upon which to test the best methods of growing forage for the Army horses and mules. Preliminary plantings by the Army in cooperation with this station have already been made on 9 acres of this tract. One of the handicaps under which the work is conducted at Schofield Barracks is the fact that, although there is an annual rainfall of about 35 inches, yet this occurs as torrential rains during the winter season, or in the form of light showers which do not penetrate deeply, especially if the soil is at all compact. Furthermore, the soil in question does not have normal water storage capacity.

ALGAROBA INVESTIGATIONS.

The increasing importance of the algaroba has led to the inauguration of some new lines of work which promise to develop into an important station project. There has been some discussion as to the native home of this tree which was introduced into Hawaii nearly a century ago and which has since assumed great importance as a source of firewood, honey (flowers), and cattle feed (pods). It has been claimed that it is one of the mesquites of the southwestern United States which, on being transferred to the more favorable climate of Hawaii, has developed into a large tree. A comparison with several available forms of the mesquite seems to indicate that it is a different species. In cooperation with the Bureau of Plant Industry, United States Department of Agriculture, seeds from various species of the genus Prosopis have been obtained, and as fast as these are received they are planted on the station grounds. It is expected that ultimately one or more lots of the seedlings will develop into trees comparable with the local algaroba grown under similar conditions. This will furnish a clue to the original source of the local species. It seems probable that the species is a South American one.[1]

[1] In a magazine entitled "Peru of To-day," an illustration, published some three years ago, was noted as picturing trees resembling very closely the local algaroba tree, while the statements regarding the character and utilization of the pods furnished further evidence that the local tree may come from the same stock as the South American species.

HORTICULTURAL INVESTIGATIONS.

The pineapple work has continued to occupy an important place in the activities of the horticultural division. The seedlings reported upon in the annual reports for 1913 and 1914 have now fruited. The showing made by the first set of seedlings was such that special efforts were made to obtain another supply of seeds, which occur so rarely in cultivated pineapples. By singular good fortune the station was able during the past year to obtain several thousand seeds through the courtesy of the management of the pineapple canneries of Libby, McNeill & Libby of Honolulu (Ltd.), the Hawaiian Pineapple Co. (Ltd.), and others. The wide variation shown in the former plantings makes it probable that the present new plantings will show some promising variations.

The work of assembling pineapple varieties from other parts of the world is progressing favorably. It is thought that there may already be in existence pineapple varieties which will prove superior in Hawaii or may be of use in cross-pollination experiments for the development of especially adapted varieties.

The work with the litchi has been mainly in developing methods of controlling the erinose disease, which is threatening some of the best trees in the islands. Considerable attention has also been given to the question of improved stocks for grafting and budding. The seeds are peculiar in that after removal from the fruit they either sprout or dry up and die within a week. This characteristic has in the past prevented the shipment of seed for long distances. Methods recently developed have been so successful that seeds have been sent as far as Florida, arriving there in excellent condition for immediate planting.

Plant-breeding work with mangoes, avocados, and papayas has been carried on during the flowering seasons of these species. The peculiar requirements of the different species have necessitated the development of a special technique in each case in order to obtain satisfactory setting of fruits. Apparent hybrids have been produced between the Chinese wood-oil nut and the Hawaiian kukui nut, it being desired to develop a hybrid the oil from the nuts of which shall be intermediate in certain characters between the oil of the parent trees, a result greatly desired by commercial dealers in drying oils.

Numerous plantings of various species of tropical plants, mostly trees, have been made during past years at the Tantalus substation, situated, at an altitude of about 1,000 feet, at the upper end of the experiment station reservation. The histories of the individual plantings are being worked up, and those completed to date have been included in this report as a matter of record.

The distributions of plant material have been largely confined to hibiscus cuttings, spineless cactus slabs, citrus seedling stocks, citrus budwood, budded seedlings of avocado and mango, and seeds of papaya. It has been decided to discontinue the distribution of plants as soon as they pass beyond the experimental stage and become suitable for commercial handling.

CHEMICAL INVESTIGATIONS.

With the recognition of the necessity for the maintenance of the humus and nitrogen content of island soils, the rôle of the various available leguminous plants becomes increasingly important. There are over a score of cultivated and wild species which are more or less efficient as green manure crops for keeping up the fertility of the soil. In order to determine which of the species are most efficient as green manures, a series of experiments has been carried out and the results submitted for publication. Those legumes should be grown the seed of which is available and which make the best growth under prevailing conditions. A number of wild legumes were found to be worthy of further test as green manure crops. It has also been found that the succeeding crop should be planted as soon as possible after the legume crop has been turned under, as the nitrate leaches rapidly from the soil and is thus lost to the new crop.

The importance of the pineapple industry has led the chemical division to devote considerable time to the pineapple problems of the islands. The "Kauai pineapple wilt" is proving most troublesome on the island of Kauai. This wilt seems to be correlated with the presence of a certain soil type, and experiments are under way to determine what treatment of such areas is most effective.

The yellowing of pineapple plants on many of the pineapple plantations on the island of Oahu was determined some years ago by this station to be due in some way to the presence of large quantities of manganese in all areas producing this effect. All the details of just how the presence of manganese induces the unhealthy condition of the plants were not worked out, however. It is believed by the present chemist that the presence of manganese so inhibits the absorption of iron by the plant that chlorosis rapidly develops. This happens in spite of the fact that the soils in question are very heavily impregnated with iron compounds, as much as 30 per cent of ferric oxid occurring at times. With the recognition that the real trouble was chlorosis, due to lack of iron in the plant itself, the standard remedy for chlorosis due to lack of iron at once suggested itself. A solution of iron sulphate was applied to the plants both as a spray and with a brush. The result was very marked, the yellow plants rapidly taking on a rich green color and the undersized, red, and

stunted fruits soon becoming normal. Experiments are under way to determine the most economical iron compound to use, the number of applications necessary, the optimum strength of the solution, and other practical points arising in connection with the application of the solution on a commercial scale where thousands of acres must be treated with the greatest possible economy of time and labor.

Some studies were made regarding the hydrocyanic acid content of cassava, which is coming into some prominence as a source of starch, while the waste gives promise of value as a feed for hogs. An improved method for determining small amounts of hydrocyanic acid has been developed by the chemist during the year and an account of the method published.

An analysis of the edible canna indicated that it possesses about the same food value, pound for pound, as does the Irish potato. This work will be followed up, as the production of Irish potatoes on the islands is a most hazardous undertaking, due to the ravages of blight and related diseases.

PLANT-DISEASE INVESTIGATIONS.

The division of plant pathology was inaugurated June 1, 1916, by the transfer of the present pathologist from a similar line of work in the Bureau of Plant Industry, United States Department of Agriculture. A large part of the necessary equipment was purchased before he left Washington so that as little delay as possible would ensue in equipping the pathological laboratory for the study of the various plant diseases in the islands. A number of harmful diseases have been definitely located and studies already have been commenced concerning late blight of Irish potatoes and a leaf spot of sweet potato. Preliminary observations also have been made on the late blight of celery. Wilt of banana, taro rot, and anthracnose diseases of avocado and mango will also be investigated as rapidly as possible.

AGRONOMIC INVESTIGATIONS.

Work with such food crops as rice, taro, and potatoes has been continued largely in cooperation with commercial growers. The potato industry continues to be hampered by the diseases which seldom fail to destroy the crop. The plantings of velvet, muth, and kulthi beans have shown these crops to be especially promising as green manure plants. A promising shrub (*Crotalaria madurensis*) for use in coffee nurseries has been under test again this past year. It is able to withstand, and in fact thrives best under, considerable shade. Various clovers have been tried at the central station, but the low altitude appears to be unfavorable to their best growth. They

are not to be recommended except possibly for the higher elevations, where they ought to furnish pasturage, hay, or green cut feed. Tests with small grains indicated promise for the production of grain hay, but the yields of grain thus far have not been such as to make it possible for them to compete with imported grains. The tests with the grain sorghums as a source of grain for feeding stock were much more satisfactory. A number of these sorghums are especially promising as chicken feed. At present most of the grain for feeding the numerous flocks of chickens in the islands has to be imported. In order to obtain material for crossing Japanese sugar cane with ordinary sugar cane a plat of the former is being allowed to stand indefinitely to determine whether it will flower in this latitude.

A considerable amount of work, agronomic in character, has been accomplished at the substations and demonstration farms. In most instances this work has been undertaken to solve some pressing local problem, but many of the results are of wider application, at least in a general way.

EXTENSION WORK.

Through the extension features of its work the experiment station comes into closest contact with the small farmer and his farm. The extension division has worked out several methods whereby the farmer can be made familiar with the best agricultural practices, as well as the best varieties and kinds, of crops to grow. The difficulties of travel and the remoteness and isolation of many of the farming districts naturally handicap the station in its attempts to reach such sections except at irregular and infrequent intervals. These rather infrequent visits are supplemented in a number of ways. Timely articles are written for the local press; local demonstrations are arranged on the land of the leading farmers in a given section; and attention is called to the fact that individual problems will at all times be given attention by letter and, if practicable, by a personal visit on the next trip to the section in question. Also, a number of farms are devoted primarily to the development and demonstration of the best agricultural practices for the sections in which they are located. These also serve as sources of supply for seeds and cuttings of the improved varieties constantly being distributed.

It has become increasingly evident here as elsewhere that the problems of marketing farm crops are quite as important as their production. To this end farmers' cooperative organizations have been encouraged to standardize their products, study the market requirements, and develop cooperative buying and selling to as great an

extent as appears to be practicable. Remarkable interest is being manifested in the two county fairs, preparations for which have been under way for some months. The station is utilizing these opportunities to bring home to the visiting farmers many of the object lessons it wishes to teach.

GLENWOOD SUBSTATION.

The Glenwood substation, which has been carried on in cooperation with the Territory of Hawaii, was organized in part as an experiment station and in part as a demonstration of the possibilities of small farming operations under the extremely rainy conditions prevailing throughout the section in question. Some idea of the difficulties under which a farmer must work in this section may be obtained from the Weather Bureau records for the station, commencing January 1, 1916, which show only 9 clear days and a rainfall of 121.52 inches for the 6 months ending June 30, 1916. The same period shows 154 rainy days, June taking the lead with 30 rainy days. The principal work has been carried on with the dairy herd and the poultry flock. The demonstration of the importance of testing the weight as well as the number of eggs laid by an individual hen is probably the most important contribution of the station to the advance of poultry breeding. The studies on the development of feed stuffs which can be grown locally have also brought promising results. The edible canna not only promises well as a hog feed, but culinary tests with it as human food indicate that in emergencies the canna could without hardship be substituted for potatoes. It is a rapid-growing, heavy-yielding crop which might also be utilized as a commercial source of starch. The tops furnish a large amount of green forage which is eaten readily by cattle and poultry. Jerusalem artichokes have also given promising results, although they apparently must be dug only when needed on account of rapid decay after digging. Provision was made by the last Territorial legislature for necessary traveling expenses of the superintendent of the substation while on demonstration trips on the island of Hawaii. Unfortunately, no provision was made for the employment of a substitute while the superintendent was away on such trips, and the necessity of maintaining the records at the station prevented his absence from the station for more than a few hours at a time. He has, therefore, been able to do extension work on only a very few occasions, when some member of the staff of the central station was able to substitute for him at Glenwood. Considerable extension work has been done, however, members of the central station staff using the Glenwood substation as a base of operations.

TERRITORIAL MARKETING DIVISION.

The last session of the Territorial legislature made an appropriation of $12,000 a year for the running expenses of the Territorial market and $14,400 for a market building. In addition $7,500 was made available as a revolving fund for use as a working capital. The division has continued to lend its efforts to the service of the small farmer on the one hand and to the convenience of the consumer on the other. The new quarters are conveniently located and contain retail, wholesale, and storage rooms, as well as rooms for candling eggs, fumigating seeds, etc., and dressing poultry.

The need of an outlet for surplus products led to the establishment on July 1, 1915, of a marketing branch in San Francisco. This branch has been reasonably successful in handling miscellaneous shipments, but the pineapple shipments were not a success, owing to heavy spoilage and glutted markets.

More and more attention is being paid to the grading and packing of farm produce. It is not easy for the isolated producer to realize the advantage in catering to the better class of trade which demands uniform goods in uniform packages. The division is planning to provide at cost standard containers for various forms of farm produce.

Another feature of the marketing work has been the establishment of a retail department for those desiring to do their marketing in person and thus save delivery charges. The relations established with the various producers throughout the islands make it possible for the experiment station, especially through its extension division, to keep in closer touch with the farmer and his problems than might otherwise be the case. The problems of production ordinarily are quite different from those of marketing, but by cooperation between the two lines of work it is often possible to indicate improved farm practices which will result in better products for marketing purposes.

REPORT OF THE HORTICULTURAL DIVISION.

By J. E. Higgins.

The work of the horticultural division has continued along the lines of investigation that have been pursued for some years past. Few strictly new lines have been undertaken, but a number of new projects have been developed out of older ones through increasing emphasis laid upon certain phases of horticultural activity. Some investigations relating to the pineapple industry have been carried on for a long time, but there has been no opportunity for such development as the importance of the industry in Hawaii would justify. During the year just closed it has been possible to begin some work

in the breeding of pineapples upon a larger scale than formerly. The litchi has also demanded increased attention. The project relating to the top-working of the mango and the avocado by bark grafting and scion budding has been closed, the final results having confirmed those recorded in the annual report for 1915. The present tendency of the work of the horticultural division is toward larger attention to plant breeding.

PINEAPPLE INVESTIGATIONS.

The work of breeding and collecting new varieties of pineapple is believed to be of considerable importance in connection with the Hawaiian pineapple industry. There are several possible methods of procedure in this matter, the first being the collection of varieties of pineapples at present in cultivation in different parts of the world. There are few varieties that have shown sufficient merit to become established as commercial sorts. It is, however, worthy of note that kinds which have not been at all successful in some pineapple-growing countries have proved remarkably successful elsewhere. The Cayenne, for example, has never found much favor in Porto Rico, where the Red Spanish has been so successfully grown, while in Hawaii the Cayenne is almost the only commercial variety. It is not improbable, therefore, that some of the little known varieties may prove to do better when introduced into Hawaii than they have done elsewhere. Attempts have therefore been made to secure as many as possible of the world's varieties, but because of the prevalence of certain diseases it has not been possible up to the present time to secure a very large number. Through the Porto Rico Agricultural Experiment Station a considerable number of the varieties grown in that island were obtained, and later one or two additional varieties were secured in Cuba and Florida. Efforts are being made to obtain a much larger collection of varieties from different parts of the Tropics.

Another method of securing new varieties is by means of the crossing of established sorts. Since none of the introduced plants have as yet flowered, it has not been possible to carry on this phase of the work except in a very limited way with pollen which has been secured through the courtesy of a local pineapple grower who had flowering plants of the variety Queen.

A still further means of securing new varieties lies in the growing of seedlings from the plants which on rare occasions produce seeds in the commercial pineapple fields in Hawaii. Four years ago a few seeds were secured and planted, and some of the resulting plants produced their first fruits in June, 1916. These seedlings have shown as wide variations as might be expected in the crossing of any two

varieties of pineapples. Some are quite vigorous, while others are almost totally lacking in vigor. Some of the plants are green in color, while others from the same seed stock show a very brilliant red coloring. In some the leaves are narrow, in others broad. Some of the plants are quite as smooth as the Cayenne, while others are extremely spiny.

During the past fiscal year several thousand pineapple seeds were secured through the cooperation of a number of the pineapple canneries. It is interesting to note how rarely these seeds occur. In fact, the canneries may in some seasons run through millions of fruits without finding any seeds. During a part of the winter season of 1915–16 seeds were found with comparative frequency in fruits brought to the canneries. For example, in a run of 63,000 fruits, 9 were found with seeds. In another run of 48,000 fruits, 4 were found with seeds. It is estimated by the weight of the seed that about 2,433 seeds were obtained from these 13 fruits. With such frequency of occurrence there should be no difficulty in securing any reasonable number of seedlings, but frequent seed bearing seems to be very unusual.

Satisfactory methods have been devised for the germination of pineapple seeds and the growing of the young seedlings beyond the critical period. There are several essential conditions which must be provided, including perfect drainage, constant and uniform moisture supply, sufficient heat, and prevention of excessive growth of algæ on the surface of the seed bed. To obtain these necessary factors the following plan has been worked out: An inch or more of broken rock is placed in the bottom of the pot and above this the pot is filled to within about $1\frac{1}{2}$ inches of the rim with a porous soil, on the top of which a layer of sand about a quarter of an inch thick is placed. This sand must not be of coral origin, since the lime in the coral is extremely detrimental to young pineapple plants. Molding sand, such as is used by ironworkers, has been found satisfactory. On this sand the seeds are placed, thus securing for them perfect drainage while permitting the roots of the seedlings to penetrate easily the soil beneath. The surface of the sand is covered with coconut-fiber dust mixed with a little powdered charcoal, which retards the growth of algæ and does not bake as does soil. The whole pot is then placed in a larger pot and the intervening space is packed with moistened sphagnum moss. This prevents sudden changes in moisture conditions in a climate where earthen pots dry out quickly on the sides as well as from the upper surface. Water is never applied directly to the top of the soil but when necessary the inner pots are removed and placed in water which rises to the surface. Plate I, figure 1, shows this method of starting pineapple seedlings.

A closed glass box in the greenhouse has been found to be advantageous but not essential. The close atmosphere and high temperatures aid in the early germination of the seed. Under such conditions pineapple seedlings begin to appear about 37 days after planting, while in the open, with cool winter temperature and without the close, damp atmosphere, sometimes two months or more is required for germination.

When the seedlings begin to appear some shade is necessary. Too intense light causes the plants to lose their green color and their vigor. A cheesecloth over the plants or a thin covering of whitewash on the glass of the box is sufficient, if the lights of the greenhouse have been reduced for other kinds of plants. In Plate I, figure 2, is an illustration of young seedling pineapples with the root system and the seed coat still attached.

LITCHI INVESTIGATIONS.

The investigations of the litchi (*Litchi chinensis*) have developed into an important part of the work of the horticultural division. During the year just closed attention has been given chiefly to an investigation of methods of propagation, preservation of the seeds, and preservation and shipping of the fruits. The experiments in grafting the litchi on the longan (*Euphoria longana* or *Nephelium longana*) have been continued and have proved quite successful, so far as the making of the union is concerned. The growth is very satisfactory, but it is too early to know what may be the ultimate influence of scion and stock on each other. Budding has also been tried and, although it has not succeeded so well as bark grafting, there appears to be no reason why methods should not be worked out for the budding of the litchi either on stocks of its own species or on some related species. Now that the litchi is attracting so much attention in Florida, as well as in Hawaii and elsewhere, attention should be given to the adaptability of various stocks to different conditions. Since the litchi makes a rather slow growth, stocks of more vigorous growth might be of great advantage. A more hardy species might lessen the risks from frost in the attempt to push this industry outside the Tropics. Resistance to certain pests might also be secured in this way.

The seeds of the litchi are extremely perishable, retaining their viability under ordinary conditions only two or three days. Unless they can be preserved in some way, they must be planted immediately after being taken from the fruit. As an aid in the distribution of the species, it was important to devise means for the preservation and shipping of the seeds. Experiments conducted by the station have demonstrated the possibility of preserving the seeds for

FIG. 1.—PINEAPPLE SEEDLINGS IN DOUBLE POTS.

FIG. 2.—PINEAPPLE SEEDLINGS, SHOWING ROOT SYSTEM.

FIG. 1.—FLOWER CLUSTER OF MANGO.

FIG. 2.—SAME FLOWER CLUSTER PREPARED FOR ARTIFICIAL POLLINATION.

several weeks and of successfully shipping them long distances by mail. Over 1,000 seeds were sent in one shipment to Florida, and were reported to have arrived in excellent condition. The method used consisted in packing perfectly fresh seeds in sphagnum moss very slightly moistened and wrapped in waxed paper surrounded by corrugated strawboard and an outer wrapper. It is important to avoid excessive moisture, as this hastens the germination of the seeds. In the shipping experiments water was added equal to half of the weight of the dry moss.

On February 3, 1916, the attention of the station was called to an apparently serious disease of the litchi. Careful investigations showed this to be due to the work of very large numbers of mites which produced galls and caused the leaves to become much distorted and covered on their under surface with a brown, woolly growth composed of trichomes, or plant hairs. Because of the similarity of this injury to the erinose disease of the grape, which is caused by another mite of the same genus, the name litchi erinose has been applied to the malady. The mite proved to be an undescribed species of Eriophyes. Experiments were undertaken immediately to determine methods for the control of the pest, and an efficient remedy has been found in spraying the tree several times with nicotin sulphate and whale-oil soap, mixed according to the following formula: Ten ounces of nicotin sulphate, $1\frac{3}{4}$ pounds of whale-oil soap, and 50 gallons of water.

Before spraying it is advisable to remove the leaves that have been most seriously injured, since these are of little use to the tree. In most cases these leaves do not represent a very large proportion of the foliage. This procedure aids in getting the mites rapidly under control, since it is difficult to make the spray enter every deep gall and penetrate the woolly covering of the leaf. If the mites are known to be present, spraying early in the season will probably keep them well in check without the necessity of removing any leaves. It is worthy of note in this connection that the longan tree, a related species, has not been found infested with this mite, although surrounded by infested litchi trees.

A survey of the city of Honolulu showed the erinose disease to be prevalent on litchi trees in several parts of Nuuanu Valley and the Kalihi district, but it was not found at Moanalua or in any other portions of the city.

CROSS-POLLINATION OF THE AVOCADO.

Owing to the illness of V. S. Holt, assistant horticulturist, during the season when the avocados were in flower, progress was somewhat delayed on this project. Prior to Mr. Holt's return to the work,

James Cowan devoted some time to this project. Studies have been made of the flower, the maturation of pollen, and the technique of hand pollination, including emasculation and thinning the flowers. The proper thinning of flowers was found to be a very important factor in success, as improper thinning causes many of the hand-pollinated flowers to fall. It was not easy at first to effect cross-fertilizations, but before the end of the season a considerable number of apparent crosses were made successfully.

CROSS-POLLINATION OF THE MANGO.

The location of this work for the present year was shifted from the station experimental orchards to Moanalua Gardens, near Honolulu, because of the total failure of the station trees to flower this season after the heavy crop of July and August, 1915. Through the courtesy of the management of the Moanalua Gardens, it was possible to carry on the work there but under greater difficulties because of the distance from the station and the necessity of frequently visiting the trees before and after pollination.

The first phase of the work was the determination of a suitable technique for the pollination of the mango, and the second, the origination if possible of new varieties combining desirable characters now found in different varieties, as, for example, the high color of the Scott with the flavor and texture of the Pirie. It is felt that much has been accomplished in relation to the development of an efficient technique in so far as the results can be judged by the setting of the fruits, a considerable number of which were nearly mature June 30, 1916, being apparently the result of cross-pollination. These crosses include the varieties Scott, Pirie, Kavasji-Patel (Cowasjee-Patel), Alphonse, Paheri, Java, and a new unnamed sort.

On the mango there may be several hundred flowers in a single cluster which is able to mature only a few fruits (Pl. II, fig. 1). In cross-pollinating, it is necessary to select a few of the best flowers and to cut out the others to prevent their setting fruit. This makes it possible to segregate the selected flowers and protect them from chance fecundation by covering the cluster with a paper bag. Frequently the best flowers are found on the very short branchings near the outer end of the central axis. When such is the case, the flowers are removed from the larger side branches (see Pl. II, fig. 2), but these side branches must not themselves be cut off or the whole cluster may fail. The flowers at the end of the cluster are not disturbed. In carrying on this pollination work, flowers are prepared the day before transfer of pollen is made. After the flowers have been emasculated and any others that might pollinate them have been removed, the whole cluster is covered with a large paper

bag which must be removed for pollination and be replaced immediately. Later flowers on the cluster may be operated upon in the same manner.

MISCELLANEOUS BREEDING WORK.

The work in papaya breeding has proceeded along the lines indicated in earlier reports and in a bulletin of the station.[1] There are at the present time no specially important developments to be recorded. A number of new plantings have been made from seeds collected from the cross-pollination of different forms and some of these plants are now coming into fruit. The chief work at the present time includes the hand-pollinating of elongata forms for the purpose of securing a strain which will produce this type of fruit with the greatest possible uniformity, the crossing of certain forms to secure further data relating to the determination of sex and the combining of desired characters.

The 72 seedlings, believed to have resulted from the attempted hybridization of the Chinese wood-oil nut (*Aleurites fordii*) with the Hawaiian kukui nut (*A. moluccana*) and referred to in the annual report for 1915, have been transplanted to the Tantalus substation where both of the parent species succeed better than at the lower altitudes. The seedlings rather closely resemble the female parent in most cases, but present some noticeable variations which are thought to be due to hybridization.

MISCELLANEOUS FRUITS.

The general variety and cultural tests with tropical and subtropical fruits have been continued, including the establishing of plantings of a large number of species and varieties as a basis for any further experimental work which it may seem advisable to undertake. The citrus orchards at the central station are in better condition than they have been for some years past, owing in part to favorable weather conditions with frequent rains which have relieved the difficulty arising from shortage of water. Another factor which contributes to the present condition of the orchards is the better control of insect pests than in the earlier years. The Mediterranean fruit fly, however, continues to be a serious pest in case of oranges and grapefruit, limes being less injured than these and lemons suffering least of all the citrus fruits. The Villa Franca and the Eureka lemons have borne heavily in the main orchards, and on Tantalus, at an elevation of about 1,000 feet, where a few trees of Genoa lemons have been planted, the results are very satisfactory. It would seem

[1] Hawaii Sta. Bul. 32 (1914).

that a larger proportion of the lemons consumed in Hawaii might be grown here.

The mango crop for the summer of 1916 in the station orchards is almost a complete failure, as is the case with mangoes in most parts of Honolulu. This is probably due in part to the continuous heavy rains during the flowering season and also in part to the very heavy crop during the summer of 1915. It is probable that a severe thinning of the fruits in the early part of 1915 would have resulted in a finer quality of fruit in 1915 and an increase in production in 1916.

The avocado orchard, which is on rather heavy soil underlaid in places by rock, suffered from the excessive rains during the winter season, but the trees which escaped this injury set a fair crop in 1916.

Feijoa sellowiana has made two attempts at fruiting, one during the past year, but has failed to bring fruit to maturity. This new fruit, commonly known as the pineapple-guava or feijoa, is now attracting much attention among the growers of subtropical fruits in California and Florida. It is indigenous to western Paraguay, southern Brazil, Uruguay, and Argentina, where its fruits are highly esteemed. The fruit has the appearance of a small guava and somewhat resembles the pineapple in flavor. These characteristics have given rise to the name pineapple-guava. The two trees in the station collection have made good growth and appear to be in a thiriving condition, but both have been slow in coming into bearing, and, as stated above, neither has yet matured a crop, although the larger of the two was well loaded with fruits which grew to about three-quarters the normal size before falling.

Some experiments in grape culture have been undertaken on a cooperative basis with a grower at Wahiawa on the island of Oahu. The vines planted are of the Hawaiian strain of the Isabella variety which has given best results in these islands. If other varieties are grown they will be grafted on these stocks. The experiments have included the trial of different methods of preparation of the soil, the use of fertilizers, and the control of the Japanese beetle (*Adoretus umbrosus*). Other experiments may be developed as the vineyard progresses.

Preparations have been made by F. G. Krauss at the Haiku substation for planting several acres of gulch land to the more important tropical and subtropical fruits, as avocados, mangoes, oranges, limes, lemons, grapefruit, grapes, etc.

MISCELLANEOUS PLANTINGS AT TANTALUS SUBSTATION.

For over 20 years miscellaneous plantings have been made in the vicinity of what is now the Tantalus substation. Some of the early plantings were made before the establishment of the experiment station and have continued under observation until the present time.

From time to time since the establishment of this experiment station, miscellaneous plantings have been made, mostly of material which was thought to require an elevation higher than that of the central station in Honolulu, which is only a little over 100 feet above sea level. Most of the plantings were tree stock, which requires a rather long period for maturity. It was thought, however, that for purposes of record the available notes of previous years and the current notes should be assembled and published. The notes on a number of species are appended.

Two loquat trees (*Eriobotrya japonica*) were planted in January, 1907. The trees were secured from the California Nursery Co., Niles, Cal., and were of the Giant and Victor varieties. The trees have made healthy and vigorous growth and have borne regularly for several years. The fruit of the variety Giant is large, bright orange in color, and is produced in large clusters. The flavor is considered very good and the fruit is considered adapted for use in sauces, jellies, preserves, pies, etc., as well as for eating uncooked. The fruit of the Victor is smaller and lighter in color. When eaten fresh the flavor is said to resemble somewhat that of cherries. The tree is more vigorous and a heavier cropper than the Giant.

Two lots of camphor trees (*Cinnamomum camphora*) have been under observation, one planted in 1894, the other in 1908. The older trees are much larger than the later plantings and are sufficiently developed for a test of their camphor content. The trees of the later planting were from 8 to 12 feet in height on April 15, 1916, with a spread of 6 to 7 feet. The trees appear healthy, vigorous, and without insect or fungus pests. They are of the variety which yields the Formosan camphor. No attempt has been made to determine the commercial value of these trees for Hawaiian conditions.

A small group of trees of *Macadamia ternifolia* is growing at the substation, the trees having been planted shortly prior to 1893. The trees are vigorous, considering their crowded condition, and some bear fruit quite regularly, indicating their value if properly cultivated and fertilized. The nut, which is known as Australian nut, is rich, highly flavored, and contains more than 66 per cent fat. The composition of the nut is given in the report of the station for 1914. The most serious obstacle to the commercial importance of this nut is its extremely hard shell.

REPORT OF THE CHEMICAL DIVISION.

By Maxwell O. Johnson.

During the past year the work of the chemical department has been mainly on problems of soil research, especially those of pineapple soils. The project on legumes as green manures was completed and the project on the acidity of Hawaiian soils continued with some

modifications as compared with previous years. The hydrocyanic acid in cassava roots was determined by a new method devised in this laboratory for the determination of this acid in very small amounts. Such soil, fertilizer, feed, and other analyses in connection with the general work of the station as were possible with the reduced staff were performed during the year.

CHEMICAL STUDIES OF THE COMPARATIVE EFFICIENCY OF VARIOUS LEGUMES AS GREEN MANURES IN HAWAII.

During the past fiscal year Miss Alice R. Thompson, assistant chemist, completed the pot experiments comparing the relative efficiency of the various legumes as green manure crops and the results have been submitted for publication. These experiments were described in the annual report for 1915.

Twenty-two varieties of legumes were grown on two Hawaiian soils of different types. Three crops were matured, using four pots for each trial of each variety. The plants were removed at maturity and weighed and the amount of nitrogen in them determined. The nitrogen was determined in the soils before planting and after removing the crop, and it was shown that the soils had lost no nitrogen and had usually made a slight gain, owing probably to decayed roots and nodules. The amounts of nitrogen contained in the various legumes were thus clearly gained by bacterial assimilation of atmospheric nitrogen. When, however, the plants were turned under with the soil and allowed to weather for several weeks, leaching of the rapidly formed nitrates took place, and when the soil was analyzed the gain in nitrogen in many cases was less than it should have been according to the amount of nitrogen turned under. This is of interest, as in most previous experiments with legumes the gain in nitrogen has been calculated by an analysis of the soil after a crop of legumes has been turned under. It is thought that the first method (that of determining the nitrogen in the crop removed and showing that the soil has suffered no loss in nitrogen, or deducting the loss if there should be any) gives results by which the legumes can be better compared with other nitrogenous fertilizers, as these fertilizers also suffer loss by leaching in the soil. These results would indicate that unless a planting is made soon after turning under a green manure crop there may be a considerable loss of quickly available nitrogen.

LIMING AND SOIL ACIDITY.

It is remarkable that, in spite of the great excess of bases found by analysis in Hawaiian soils, many of these soils should show a high degree of acidity when tested by the Veitch and other methods. In view of this fact and the increasing evidence of the benefits of liming in the States, a thorough investigation is being made of the character

of the acidity of Hawaiian soils and the effects of lime on their properties. Large quantities of soils from three different islands (Hawaii, Oahu, and Kauai) have been secured, and the results of tests with these, it is hoped, will be of fairly general application in the islands. On the assumption that in whatever form lime is applied the carbonate and bicarbonate will result, an investigation is being made of the reaction of Hawaiian soils to calcium bicarbonate under various conditions, and the results promise to be of considerable value.

THE KAUAI PINEAPPLE WILT.

The "Kauai wilt" of pineapples is a very serious trouble, affecting the success of many homesteaders on the island of Kauai, especially in the Kapaa district. As preliminary tests of soil samples secured from this section in connection with a general field trip by the chemist showed a very small amount of lime in the soil, with a high degree of acidity, and about half as much lime in the ash of the wilting plants as in that of the healthy ones, it was therefore thought that acidity might have some connection with the wilt. A special trip was made to the pineapple district of Kauai and a large number of soil samples secured. As one result of the analyses made, a successful correlation was worked out between the wilt and the light-yellow soils, which have been derived from lavas acted upon by steam and sulphuric acid vapor near centers of former lateral crater activity. The acidity of the samples collected corresponded closely with the field notes on the wilt. Pot and field experiments with different forms and amounts of lime are being made to determine the effect of liming.

THE YELLOWING OF PINEAPPLES ON MANGANESE SOIL.

Considerable areas in the Wahiawa, Kunia, and other pineapple districts of the island of Oahu contain large amounts of manganese. The pineapple plants on these black manganese soils are affected very seriously, turning yellow and producing little fruit, which is of inferior quality. These manganese soils and their effect on the pineapple plant have been investigated thoroughly by this station in former years and the results published.[1] In these publications the yellowing is attributed to some indirect action of the manganese in the soil, as "a modification in the osmotic absorption of lime and magnesia." Up to the beginning of 1916 the only treatment that has been at all successful has been the application of large quantities of stable manure. This method, however, is very expensive, and the supply of available manure is limited.

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[1] Hawaii Sta. Buls. 26 (1912) and 28 (1912), Press Bul. 23.

It appeared to the present chemist of the station that the pineapple plants were suffering from an insufficient supply of iron, a small amount of which is considered necessary for the proper functioning of the chlorophyll. Field trials confirmed this hypothesis, since yellow and dying plants brushed with a solution of iron sulphate rapidly became green and healthy and began a vigorous growth, which has continued up to the present time (June 30, 1916). Numerous field experiments have been made on large areas of yellow plants which were sprayed with a solution of iron sulphate and in every case the treatment has proved successful. The best conditions for application, the most suitable strength of solution, the optimum number of sprayings, etc., are being worked out, but already it is apparent that this treatment will be very profitable to the growers, as excellent crops are ripening on manganese soil on which approximately $2.50 an acre for four sprayings has been spent.

HYDROCYANIC ACID IN CASSAVA.

The roots of the cassava or manioc (*Mœnihot utilissima*) contain the very poisonous hydrocyanic acid (prussic acid). Owing to the increasing cultivation of this plant in Hawaii for the preparation of starch and as a cattle and hog feed, determinations of this hydrocyanic acid were made. Previous methods for the determination of small quantities of this acid proving unsatisfactory the chemist devised a convenient and accurate method, which has since been published.[1] Some determinations of the hydrocyanic acid in cassava are of interest. Unfortunately, the varieties used could not be classified except under their vague common names of "bitter" and "sweet."

Hydrocyanic acid content of cassava.

No.	Kind.	Source.	Age.	Character of soil.	Diameter of root.	Part of plants.	Hydrocyanic acid.
			Mos.		*Inches.*		*Per ct.*
1	Sweet	Station	18	Poor heavy clay	1	Whole roots	0.006
2-A	do	do	6	Good light clay.	¼	do	.025
2-B	do	do	6	do	¼	Peel of roots	.042
2-C	do	do	6	do	¼	Peeled roots	.021
3-A	Bitter	do	6	do	¼	Whole roots	.008
3-B	do	do	6	do	¼	Peel of roots	.015
3-C	do	do	6	do	¼	Peeled roots	.007
4-A	do	do	24	do	5	Whole roots	.013
4-B	do	do	24	do	5	Peel of roots	.025
4-C	do	do	24	do	5	Peeled roots	.007
5	Sweet yellow	Waialua, Oahu		do	1½	Whole roots	.006
6	Bitter	Kauai	9	do	1	do	.014
7	do					Waste (from whole roots used for starch manufacture).	.003
8	do					Waste (from peeled roots used for starch manufacture).	.0008

[1] Jour. Amer. Chem. Soc., 38 (1916), No. 6, pp. 1230–1235.

From the results obtained it would appear that cassava waste is perfectly safe for use as a hog feed, if, as is usually the case, it is boiled before feeding. Moore[1] estimates 0.008 per cent or more of hydrocyanic acid as dangerous in feeding the fresh root. The chemical division would caution against the use of cassava for feed unless the finely divided roots are thoroughly boiled with two or three changes of water.

THE EDIBLE CANNA.

The edible canna (*Canna edulis*), known also as the "Queensland arrowroot" and "tous-les-mois," appears to be well suited to Hawaiian conditions. Analyses were made of samples submitted by J. B. Thompson, superintendent of the Glenwood substation, Hawaii. Two sizes of canna rootstocks were analyzed. No. 1 refers to the small rootstocks about 2 inches long and No. 2 to rootstocks 5 or 6 inches in length. The results are figured on both the fresh and the water-free basis. The results given for the fresh rootstocks are most interesting. They show little difference in the ash, fiber, fat, and protein for the small and large rootstocks, but a remarkable increase in the nitrogen-free extract in the larger rootstocks. The following table gives the results of the analyses:

Analysis of the edible canna.

Constituent.	Fresh basis.		Water-free basis.	
	No. 1.	No. 2.	No. 1.	No. 2.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Water	81.58	65.86	.....	.....
Total solids	18.42	34.14	100	100
Ash	.81	.81	4.39	2.37
Crude fiber	.54	.64	2.93	1.88
Fat (ether extract)	.13	.15	.71	.44
Protein	1.37	1.20	7.45	3.52
Nitrogen-free extract (starch, sugar, gums)	15.57	31.34	84.52	91.79

REPORT OF THE DIVISION OF PLANT PATHOLOGY.

By C. W. Carpenter.

The division of plant pathology of the station was established June 1, 1916, with the transfer of the present pathologist from the Bureau of Plant Industry, United States Department of Agriculture. Previous to June 1, the investigations of diseases of plants at this station had been limited to such studies as could be made by the members of the staff incidentally along with their regular lines of work. It had become more and more evident, however, that the dis-

[1] U. S. Dept. Agr., Bur. Chem. Bul. 106 (1907), p. 16.

eases of the economic plants of the islands demanded more adequate attention than had been given them.

The pathological laboratory has been fairly well equipped and is being brought into working order as rapidly as possible. Arrangements have been made for the installation of an herbarium case in which pathological specimens will be deposited as they become available by collection and exchange.

The most important diseases at present calling for attention are late blight of Irish potato, late blight of celery, anthracnose of avocado and mango, taro rot, and banana and pineapple wilt. Other plant diseases have been observed as follows: Leaf spot and fruit rot of papaya; leaf spot, stem blight, and fruit rot of guava; leaf blight and pod blight of Lima bean and string bean; common scab of Irish potato and also a wilt disease of this host which has been confused with Phytophthora blight; and cabbage soft rot. Leaf injuries probably of fungus origin have been noted on the following hosts: Lemon, orange, fig, peach, poha, coffee, carrot, sorghum, loquat, Java plum, corn, rutabaga, sweet potato, and pineapple. Knotting and dwarfing of young corn plants appear to be serious in certain localities. Specimens of stem blight of mammee apple (*Mammea americana*) similar to that on guava have been collected.

REPORT OF THE AGRONOMY DIVISION.

By C. A. Sahr.

During the year new projects on cassava and fiber plants were inaugurated. The project on cassava includes test of varieties for the production of forage and starch, the determination of best cultural methods, and a study of methods for the utilization of cassava waste. The project on fiber investigations has for its object the determination of yield and quality of different fiber plants, especially sisal (*Agave sisalana*) and sunn hemp (*Crotalaria juncea*).

AQUATIC CROPS.

The work with rice and taro in the vicinity of Waiau, Oahu, is progressing favorably. Checks have been made upon average yields obtained from the 1915 spring and fall crops from the plat designed to serve for the test of aeration of soil for rice. Owing to excessive rains and high winds the 1916 spring crop of the nonaerated plat fell 51 per cent below the yield of the same in 1915. In the aeration soil test for the spring crop of 1916 the nonaerated plat outyielded the aeration plat by 18.7 per cent, the increase favoring nonaeration being 490 pounds of rice paddy.

The test of aeration of soil for taro was begun in the middle of August, 1915. The fertilizer test with taro was inaugurated at the same time, and it was expected that the plats would be harvested during the first week in July, 1916. Further work with aquatic crops has been commenced in cooperation with Jonathan Aiau at Waialua.

POTATOES.

The work with potatoes for the year at the central station was limited to the planting of three varieties to obtain material for pathological investigations. The manured portion of the plat was divided into three sections for further tests with Bordeaux mixture and lime sulphur spray for the control of fungus diseases. In a variety test at the Tantalus substation (elevation 1,000 feet), the Early Rose outyielded the Burbank and the American Wonder. In a culinary test of these varieties, the Burbank, although exceeded in size by the American Wonder and the Early Rose, proved superior in mealiness and flavor.

LEGUMES.

Four new varieties of velvet beans were received from the Office of Forage Crop Investigations, United States Department of Agriculture, during April, 1915, and were grown in the variety test plats with one variety from Porto Rico (supposed to be *Stizolobium capitatum*) and seven varieties under test by this station for several years. The stands obtained from the four new varieties were too uneven for reliable yield data. Sufficient seed was obtained for a second planting.

Another legume of unusual promise as a green manure or forage crop has been found in the muth bean (*Phaseolus aconitifolius*), seed of which was received from the Bureau of Plant Industry. As with kulthi (*Dolichos biflorus*) the water requirement of the muth bean is much lower than that of most other leguminous forage crops. The growth is at first erect but soon becomes prostrate, forming a dense mat upon the soil. Calculations from trial cuttings of muth bean grown between rows of pineapples represent average yields of about 15 tons green matter per acre for a four months' period of growth. (See Pl. III, fig. 1.)

Crotalaria candicans (S. P. I. No. 28606), of which mention under the name *C. madurensis* was made in the annual report of this division for 1915, has given considerable promise as a leguminous shrub for shading in coffee nurseries. Although somewhat checked by drought and aphis attacks in the summer of 1915, the plants failed to show material effect of damage from either of these sources of injury.

With the early fall rains considerable damage from scale was noted on the main stems and lower branches. This trouble was effectively treated with a proprietary oil spray especially prepared for the San José scale. The plants came to full bloom during January, 1916, the pods maturing in early March. A plat 8 by 8 feet having 11 plants produced 3½ pounds of seed.

Trials with *Desmodium hirtum* for several years failed to produce results of consequence. Growing the plants in shade was suggested, and a further trial was made on a plat prepared not 10 feet away from the trunk of a flourishing young algaroba tree. The growth made by the shaded plat of this legume during a period of 6 months is nearly equal to that made by another plat in the open during 15 months.

Of the true clovers (*Trifolium pratense*) planted in the forage plant garden February 27, 1915, cuttings of the red clover plats were made on January 5, 1916. The average yields of green forage for these clovers are as follows: Red clover from Switzerland (S. P. I. No. 37939), 8.55 tons; ordinary red clover (F. C. I. No. 1472), 8.45 tons; Swiss Rummellee clover or apitrefle (S. P. I. No. 37937), 2.1 tons; and red clover from Switzerland (S. P. I. No. 37938), 1.8 tons.

The clover plants have flourished in the past season of unusual coolness and humidity during the spring of 1916, and the next cutting will be made for seed in the latter part of July, 1916. A cutting of the alsike clover made January 20, 1916, represents a yield of 6.15 tons per acre. Further cutting of this stand also awaits proper maturation of seed. Of the white clovers, ordinary white (S. P. I. No. 34930) made appreciably more growth than did wild white (S. P. I. No. 38579) and Ladino white (F. C. I. No. 1482). A stand produced from *Trifolium striatum* (F. C. I. No. 1450) succumbed to drought in the summer of 1915, while *T. dubium*, replanted on April 17, 1915, produced a good stand and was maturing seed in July, 1916.

SMALL GRAINS.

A test of small grains for yields of grain and forage was begun December 15, the experiment including five varieties of winter rye, two varieties of oats, and one variety of winter barley. As in previous tests the ryes made the best growth at the start, but to date only the Mexican winter rye (Pl. IV, fig. 1) has headed out, and the stand is so sparse as to indicate exceedingly unsatisfactory yields of both grain and forage. The oats stands of both the manured and check plats were harvested June 5, Fulghum yielding 70.75 pounds forage and 2 pounds 13½ ounces grain for the manured plat and 59 pounds forage and 2 pounds 5½ ounces grain for the check plat (Pl. IV, fig. 2) while Red Rustproof yielded 112.5 pounds forage and 2

FIG. 1.—PINEAPPLES INTERPLANTED WITH MUTH BEANS FOR GREEN MANURE.

FIG. 2.—DWARF ESSEX RAPE INTERPLANTED WITH MUTH BEANS.

FIG. 1.—RED RUSTPROOF OATS (LEFT) AND MEXICAN WINTER RYE (RIGHT).

FIG. 2.—JOHANNES WINTER RYE (LEFT) AND FULGHUM OATS (RIGHT).

pounds 5½ ounces grain for the manured plat, and 94 pounds forage and 3 pounds 13 ounces grain for the check plat (Pl. IV, fig. 1), indicating yields of from 13 to 22 bushels of grain per acre. The stand of winter barley has failed to head out to date.

A second planting, including five varieties each of oats, barley, and rye, and three varieties of wheat, was made March 28. Of the oats, Fulghum, Swedish Select, and Sixty Day had headed out to some extent on June 5, Fulghum taking the lead. Of the barley, only the Smyrna variety had headed out by June 5. A yellow wilted area across the center of the barley plats was found upon examination to be due to an attack of aphis. Owing to the moist and cool conditions prevailing during the spring the ryes and wheats, with the exception of the winter varieties, are expected to produce good results. Duplicates of the cereal tests described above are being made at Waimea, Hawaii, and at Makawao and Haiku, Maui, the tests in the first two districts named being made at an altitude ranging from 2,500 to 3,200 feet.

SORGHUMS.

Owing to the very limited area on which corn can be profitably raised in the Territory, attention has been given to the production of grain sorghums to supplement corn. The results of a test for yields of grain and forage with kafir corn, milo maize, and feterita in comparison with Sugar Drip sorghum, sown April 19, 1915, are given below:

Results of a comparative test with sorghums.

Type of sorghum.	Date of harvest.	Plat yields.		Acre yields.		Number of days to mature.
		Forage.	Grain.	Forage.	Grain.	
		Pounds.	*Pounds.*	*Tons.*	*Pounds.*	
Kafir corn	Aug. 5	993	5½	6	66.5	107
Milo maize	Aug. 2	748	36¼	4.52	436	104
Feterita	do	1,100	19⅝	6.65	235	104
Sugar Drip	Aug. 5	1,863	57	11.27	689	107

The low yields of grain and forage from kafir corn substantiate the statement made in the 1915 annual report that yields from this crop are very adversely affected by drought. It should be stated here, however, that the extremely low yields of grain recorded for the kafir corn in the above test are also due to harvesting before the stand obtained uniform maturity, about 10 days more being required with kafir corn than with Sugar Drip sorghum.

In the 1916 test of grain sorghum, Manchu kaoliang, dwarf milo, and dwarf kafir have been added to the number included in the 1915

test. These were sown April 15 under the most equable conditions obtainable. The first heads were noticeable in the Manchu kaoliang stand on June 1, in the feterita on June 3, and in the milo maize on June 7. The fact that kafir corn, milo maize, and kaoliang have been listed under grains in the San Francisco and Los Angeles Produce Exchange for some time past suggests the importance of the production of these crops in Hawaii, since heavy importations of grains are at present necessary.

A new long-period test for yields of forage was begun in August, 1915, and excellent stands of nonsaccharin sorghum No. 309 and of Japanese cane were obtained, the plantings being made July 17 in field N, west of the administration building. The plat of No. 309 sorghum consists of 33 rows 4 feet apart, each row containing 36 plants 2 feet apart in the row. The stand of Japanese cane was planted in 26 rows, 77 feet long and 5 feet apart, of which 13 were propagated by division of roots and the remaining half by cuttings of the canes. The stand was cut for the first time for yield of forage December 29, the estimated acre yield of the stand produced from cuttings totaling 2 tons more than the yield of the stand produced by division of roots.

GRASSES.

Cuttings of two new grasses, Napier grass (*Pennisetum purpureum*) and Cayenne grass (S. P. I. No. 38946), were received from the Bureau of Plant Industry December 24 and planted on December 29. A good stand of Napier grass was obtained, but only a single plant of Cayenne grass. The first-named produced flourishing heads throughout April, but owing to ravages by birds no seed was obtained. A large assortment of grass seeds containing a few varieties previously introduced was also received from the Bureau of Plant Industry in April, and is being held for planting when the autumn rains commence.

Demonstration plats, each 96 by 19½ feet, were planted in field N to Wilder grass (*Andropogon nodosum*), Australian blue grass (*A. sericeus*), fuzzy top (*A. saccharoides*), Natal redtop (*Tricholæna rosea*), and a triangular plat, 97 by 56 by 113 feet, was sown to Giant Bermuda grass. (See Pl. V, fig. 1.) These grass plats represent the five best drought-resistant pasture grasses for low and medium elevations. (See Pl. V, fig. 2.)

Of the grass plats in the grass garden planted in the fall of 1913, Mitchell grass (*Astrebla triticoides*), side oats grama (*Bouteloua curtipendula*), tall fescue (*Festuca elatior*), American buffalo grass (*Bulbilis dactyloides*), *Bromus unioloides*, *B. erectus*, *Paspalum notatum*, *P. nodosum*, and *P. virgatum* have continued to thrive, although severly checked during seasons of drought. Other grasses sown at the same time and sharing the same conditions of growth,

while unthrifty, still persist in their original plats. Of these, a single plat of meadow foxtail (*Alopecurus pratensis*) produced heads in May, and *Paspalum compressum* bloomed in April. Slender wheat grass (*Agropyron tenerum*), *Phalaris bulbosa*, *Poa arachnifera*, and *Bromus sericeus* furnished considerable herbage, but so far have failed to bloom.

NUT GRASS CONTROL.

As in the previous years, work on control of Japanese nut grass has proved that spraying with arsenite of soda is the most effective means of control if the spray is applied when the grass is in full bloom. Plowing with a disk plow is effective if done at intervals of four or five weeks during exceedingly dry periods. Quantities of tubers found on the surface of the soil following effective plowing and raked together after weathering for four weeks, when again planted in boxes, failed to start new growth after a reasonable period.

MISCELLANEOUS CROPS.

Cotton.—Representative stands of Egyptian, Sea Island, Columbia (upland), and Caravonica "wool" cotton have been maintained for demonstration purposes and to supply select seed of each variety.

Corn.—A repetition of the 1914 fertilizer and rotation test with Reid's Yellow Dent corn was commenced in November, 1915. The mechanical condition and moisture content of soil during the life of the stand were favorable, but after five weeks of growth the stand was materially affected by the leaf hopper (*Peregrinus maidis*), the yield of grain being so reduced as to furnish no reliable data.

Rape.—Tests with rape in previous years have generally been failures owing to the loss of the crop through drought and aphis attacks. A stand of Dwarf Essex rape obtained from a planting made May 1 is shown in Plate III, figure 2, made 32 days after sowing. The second rows on each side of the stake, cut for estimating the approximate yields of forage per acre, averaged about 11 tons produced in 50 days.

SEED DISTRIBUTION.

As in previous years the demand for seed by farmers and homesteaders has been large, chiefly for seed of pasture grasses and soiling crops. Numerous requests for cuttings of forage grasses which do not produce seed readily were filled by the division. Among these should be mentioned especially the Giant Bermuda grass, which is proving very promising for pasture and hay.

REPORT OF THE EXTENSION DIVISION.

By F. G. Krauss.

GENERAL ASPECTS OF THE WORK.

The extension division during the past year has given increased attention to the purely extension phases of the work. The writer has made seven official trips during the year, all the principal islands having been visited and numerous cooperative connections established. Nearly all the members of the entire scientific staff of the experiment station have made one or more trips to the various islands where it was possible for them to give valuable assistance along extension lines in connection with their principal lines of inquiry and investigation. Much of the extension work with farmers has necessarily been done through correspondence, nearly 800 letters having been received and answered during the year, in addition to at least an equal number handled at the experiment station at Honolulu. Fully 200 persons have visited and inspected the central demonstration farm on Maui during the past year. About 20 meetings of farmers have been attended by the station staff where part was taken in speaking and in discussions. A number of prominent agriculturists and educators have been invited to address farmers' assemblages held under the auspices of the extension division.

In addition to extension work, the division has given considerable attention to two related phases of the work. The extraordinarily wide diversity in soil, rainfall, and exposure to winds makes it impossible to lay down hard and fast rules regarding the details of the best agricultural practices upon a given farm in any particular section of the islands. Two localities well within sight of each other may require an entirely different set of crops and cropping systems. This condition of affairs calls for the working out of the best practices in each particular locality. This is being accomplished by means of cooperative field tests of different methods of crop production and demonstrations on the farms of the best farmers available and also on specially equipped demonstration farms, five of which have been established in different parts of the islands under the direct management of the extension division.

The second related phase of extension work to which attention has been given has been the organization of the farmers for their mutual benefit for business and social purposes, and especially for marketing to best advantage the products of their farms. This branch of the work, although but recently instituted, already has resulted in the organization of several important farmers' associations which have assisted in developing new markets for farm produce as well as in

helping to start several new and promising cooperative agricultural enterprises which, it is believed, will prove of material benefit to the small farmer. E. C. Moore has had immediate charge of carrying out this work of organization.

EXTENSION OF NEW CROPS AND IMPROVED FARM PRACTICES.

Probably the work of most direct benefit to the farmers at large under the present status of the development of diversified agriculture in these islands is the introduction and extension of new crops or improved varieties of established crops and the actual demonstration of improved farm practices. This division has undertaken to establish in various parts of the islands demonstration farms under its immediate control and cooperative experiments with farmers on their own farms. The object has been "teaching by doing" things which hitherto have been merely written and talked about. The demonstration farms at Haiku have had under cultivation during the past year some 60 acres in miscellaneous crops. These crops, the experiment station at Honolulu and the experimental plantings at Haiku have demonstrated, are promising for culture on a commercial scale.

WORK AT THE LOWER DEMONSTRATION FARM AT HAIKU.

This is the principal demonstration farm on the island of Maui. It is situated on the lower and drier section of the homestead tract located in Kuiaha, Pauwela, and Kaupakulua. The farm is typical of an extensive area of potential farming land now devoted to grazing. The units selected for the demonstration work appear well suited to the purpose. While it is at present held in private ownership, it has been suggested that the county of Maui take the land over and make it into a permanent institution. The value of the work undertaken is directly proportionate to the length of time over which such work extends. Cropping systems, based on crop rotation and green-manuring practices, can not demonstrate their value unless carried on over a long period. This can only be assured by State or county ownership.

Thirty-five acres is at present under crops on this farm. Both virgin land and previously cropped land are this year under test to demonstrate their comparative fertility. Careful cost accounts are being kept to determine the comparative expense of clearing land by various methods, such as hand grubbing, blasting, and power clearing. Various "methods of tillage" experiments in connection with the production of the different crops are under way.

The entire area was planted in the spring of 1916 to three established varieties of field corn developed in breeding plats maintained

by the writer for several years as a private enterprise. The entire area of corn is being intercropped, as the result of extensive experiments conducted by the writer for a number of years. These crops include the following legumes: Cowpeas, sunn hemp, soy beans, velvet beans, culinary beans (several varieties), sweet potatoes, Irish potatoes, peanuts, and other seed crops for feeding and green-manuring purposes. All are being grown in sufficient quantity to demonstrate their commercial value and also to provide means for obtaining practical figures as to costs of production. Not the least important work at this farm is the working out of satisfactory methods of storage, grading, and marketing of these comparatively new crops.

In addition to the above crops, a large number of comparative tests are being made of new crops to show their adaptability to the prevailing conditions. These crops at present include 18 varieties of cereals, which are being grown in cooperation with the agronomy division of the experiment station, some 40 varieties of grain sorghums and millets, and 10 varieties of root crops, mostly for stock and poultry feeding experiments to be conducted later. Many of these crops are being tested at the direct request of farmers in the neighborhood and throughout the islands.

All the crops at the lower demonstration farm are being grown both with and without fertilizers and with and without green-manuring crops to demonstrate the feasibility of these several practices under existing conditions. Already it has been demonstrated that high-grade fertilizers can be made to double the yield of Irish potatoes, while with field corn the commercial fertilizers have given comparatively little increase. Heavy green manuring, however, more than doubled the yield of corn. Likewise, the crops of corn on virgin soil in this particular locality are fully twice as heavy as on the land previously cropped to corn. From this it would appear that Hawaiian soils generally are lacking in humus, and plans are being made to test this theory in connection with subsequent crops.

An important phase of the cultural work being undertaken at this farm is the selection and improvement of pure strains of farm seeds especially adapted to local conditions. Begun as a private enterprise by the writer in 1912, the work to date has resulted in the establishment of a superior strain of Yellow Dent corn, two superior varieties of Irish potatoes, two new varieties of sweet potatoes, as well as a number of new legumes for green-manuring and stock-feeding purposes.

In the general distribution of seeds and plants inaugurated by this division during the past year there were distributed 6,450 sweet potato cuttings (2 varieties), 825 Irish potato eyes (2 varieties), 150 pounds field corn (3 varieties), 660 root divisions of grasses, 20

pounds grass seed, 87 pounds beans (culinary), and 100 pounds leguminous seeds (for stock-feeding and green-manuring purposes).

A number of the above crops had already become established in the immediate community from a previous limited distribution. Among the most prominent of these is Sudan grass, which in 1913 was represented by a 100-foot test row. It may be safely said that at present at least 100 acres is devoted to this valuable hay and soiling grass in the Haiku district alone. In addition to the stocks indicated above which have been sent out upon request, large quantities have been delivered to persons calling at the farm. In all these distributions the recipients have been requested to report upon the results of their trials. It is believed that such data accumulated from a wide area will in time prove of great value in establishing crop zones.

WORK AT THE UPPER DEMONSTRATION FARM AT HAIKU.

At the upper or central demonstration farm at Haiku, Maui, which constitutes the headquarters of the extension division, the principal lines of work have been with pineapples. A considerable amount of general experimental work supplementing the investigations of the station at Honolulu is being undertaken. A meteorological station, which includes temperature, precipitation, and wind velocity observations, was established in January, 1916, in cooperation with the Weather Bureau. It is planned to extend this phase of the work considerably for the purpose of further correlating crop production with climate, a new line of work recently inaugurated by the United States Weather Bureau at Washington. About 15 acres at this station is now devoted to pineapple experiments and demonstrations. Experiments are now under way in tillage, planting, fertilizing, green manuring, drainage, and determining the relative merits of various types of plants. Five acres are devoted to a cropping and feeding project which has for its purpose the restoration of worn-out pineapple lands, the most important problem which now confronts pineapple growers in Hawaii. Five acres constitute a trial ground for the testing of new crops, seed of which has been furnished largely by the station at Honolulu. At the present time more than 100 grasses, clovers, and other economic crops are being grown in comparative tests. In cooperation with the horticultural division of the station, an experimental fruit-growing project has been developed for the purpose of determining the adaptability of the protected gulch lands for the culture of grapes, citrus, and other tropical fruits. An acre and a half of land has already been cleared and a portion is now being terraced to determine the value of this method of preparing steep hillsides for the cultivation of fruits and

other crops. These experiments were undertaken by the station because of the belief on the part of settlers that these heretofore waste lands sheltered from the prevailing heavy winds might be developed into highly productive and profitable areas.

The growing demand for choice home-grown vegetables has led to a series of successive plantings of a large number of the more popular vegetables in order to determine the best season for the different varieties.

EXTENSION WORK IN CONNECTION WITH COUNTY FAIRS.

The extension division has taken the lead in the inauguration of the first Maui County agricultural fair, to be held in November, 1916. Great enthusiasm for it is being shown in every quarter. The sugar plantations and pineapple plantations are cooperating heartily with the so-called small farmer in furthering the common interests of the community. There is every indication that this fair will prove of great value to all concerned, not only for its direct practical value in showing what can be grown, but in bringing the community to a realization of the value of cooperation. This division, through the Glenwood substation on Hawaii, is taking an active part in the furtherance of the second Hawaii County fair, the first fair having proved very successful last year. It is hoped that the county fair idea will spread to each of the other islands and finally result in a great Territorial fair in which all of the counties shall participate.

MAINTENANCE OF FERTILITY OF PINEAPPLE FIELDS.

In the last annual report stress was laid upon the projects planned with a view to working out some rational system of soil management whereby the worn-out pineapple lands could be renovated. The solution of this problem becomes more and more important as the best pineapple areas become used up, as is fast being done. It is as yet too early to predict which of the several methods now being tested will prove most effective in the maintenance of satisfactory yields of pineapples.

The extensive cooperative experiments undertaken with the Haiku Fruit & Packing Co., at Haiku, in which the accumulative renovating power of green-manuring legumes is being tested over a period of five years, is progressing favorably in that the several green-manuring crops planted last fall grew well and were plowed under in the spring of 1916, according to schedule. The same area was again replanted with the exception of the one unit reserved for planting to pineapples. After the entire area has been successively replanted to pineapples and the subsequent crops harvested and weighed valuable data will become available. The experiment and demonstration,

however, will not be completed until 1923. This fact is mentioned to indicate the length of time required to conduct an experiment of this nature. Much credit is due the cooperating company for its willingness to undertake an experiment running for so many years.

Another project with the same object was planned with a view to making the land bring in tangible returns during the entire period given over to renovation by leguminous crops. This, it is hoped, will be accomplished by feeding off the crops grown on the land. The resultant gains will contribute to the support of this line of work, which was put into effect in January, 1916. In advance of the report on the completed experiment the preliminary data and estimates are given below in the hope that they may prove suggestive to those interested.

The area under experiment was planted to pineapples in October, 1912. The first crop, averaging 22.5 tons per acre, was harvested between January and November, 1914. The second (first ratoon) crop was harvested during the latter half of 1915, and yielded at the rate of 21 tons per acre. The third (second ratoon) crop (on the divisions still in pineapples) is just beginning to mature. The yield, owing in part to the unfavorable season, will probably fall below 10 tons per acre. The entire area was paddocked off into four equal subdivisions. The first paddock was pastured to four head of mules and one cow per acre during January, February, and March, 1916, and with an average of 10 hogs during April, May, and June, 1916. The area under pasture was covered with a rank growth of weeds and grass as is usual at the end of a cropping period during which weeding has been suspended for a considerable time. The live stock showed preference for the young fruits and buds and even the young leaves of the pineapple plants over the grass and weeds which would ordinarily be classed as fairly good pasturage. At the end of six months the entire herbage excepting the old pineapple stumps had been eaten off, so that the hogs had to be given a small supplementary feeding of sweet potato tops to finish out the six-months period. If an allowance is made at current rate for pasturage of cattle, the land would yield a revenue of $13.80 per acre per annum, without taking account of the remaining half of the year. Much of the value of the organic matter produced on the land is, of course, retained either in the form of stubble or manure, and this is the main object sought. However, the project as now planned calls for the shifting of the stock to the next area as soon as the other section is fed off, while the pastured-off area is immediately plowed and cropped to one of several green-manuring summer legumes. If the season is moist it is planned to plant to field corn intercropped with a legume, which, for the present purpose, is preferably the cowpea or velvet bean, either of which makes excellent feed for growing hogs, especially

when supplemented with corn. These crops may, of course, be either pastured off or harvested, cured, and fed separately. From work previously done at the central Haiku farm, where the present project is under way, it is fair to assume that a ton of shelled corn and leguminous seeds can be produced per crop per acre, and that two such crops can be grown per annum. If these estimates are realized in the present project, it will be seen that enough grain should be grown per acre during the last half of the present year to produce from 300 to 400 pounds of pork, live weight, allowing 5 to 6 pounds of grain per pound, live weight. This, with the corn stover and pea vines, will go far toward making the renovation period at least self-supporting.

ORGANIZATION WORK.

One important phase of the extension work has been that of helping the farmers to help themselves through properly organized activities. E. C. Moore, of Haiku, has had immediate charge of this line of extension work of the division. A statute covering the organization of cooperative societies was passed at the last session of the Territorial legislature. A number of cooperative societies have been formed, and the extension division has endeavored to keep in close touch with all the cooperative activities of these organizations and to render all possible assistance to them.

It has been found that the problem of the necessary bookkeeping usually gives considerable difficulty to a newly formed organization of this nature. The immediate object of most of the cooperative organizations has been the more profitable production and marketing of the special crops. The Territorial marketing division, with which the extension division is cooperating, ordinarily handles individual consignments of miscellaneous farm produce, but more closely organized effort is regarded as necessary in connection with the production and marketing of such special crops as pineapples, sugar cane, bananas, and algaroba beans. Some assistance has been rendered various groups of farmers in connection with contracts with the pineapple canneries and the sugar mills for the disposal of their products. During the year a mailing list of farmers has been prepared for the use of the extension division.

COLLABORATION IN EXTENSION WORK.

In order to reach as many farmers as possible on the outlying islands, three farmer collaborators have been engaged to devote a part of their time to the extension work. These are in homesteading sections and on the farm of the best available farmer, and while the collaborator continues to operate his own farm, he also conducts demonstrations in crop production to serve as object lessons to the

other farmers of that section. Another duty of the collaborator is to render all possible assistance to the neighboring farmers in the establishment of better markets for their crops and in the development of standard grades of production to meet the demands of the best buyers. The collaborator on Kauai, J. de C. Jerves, has been instrumental in spreading the Madeira sweet potato throughout the islands, where it has proved of exceptional merit.

The collaborator at Hilo, Hawaii, J. E. Gamalielson, has been very active and painstaking in the marketing of dairy and poultry products for the homesteaders in that district. At Kamuela, Hawaii, Mr. John McCoy and his successor, A. L. Arthur, have undertaken demonstrations in the production of crops which can be fed to live stock and thus marketed. The preliminary efforts in raising perishable products in this section were shown to be unprofitable, owing to the distance from markets for such produce and to the lack of suitable transportation facilities.

The extension work of the Glenwood substation at Glenwood, Hawaii, is under the general supervision of the extension division.

REPORT OF THE GLENWOOD SUBSTATION.

By J. B. Thompson.

POLICIES OF THE STATION.

The work of the Glenwood substation has been planned, during the past fiscal year, to conform to the necessary policy of economy enforced by a 50 per cent cut in the Territorial appropriations for this station. The activities have, therefore, been confined to lines of work requiring little financial outlay or capable of being conducted on a self-supporting basis. The labor force has been reduced to a single workman, most of whose time has been occupied in the performance of daily routine work involved in the care of the live stock. All operating expenses have been reduced to a minimum and the work has been planned with a view to using the returns for continuing the investigations. With funds available for only one laborer and with the numerous daily records required in connection with the trap-nest tests in the poultry pens, the necessity of keeping the climatological records up to date, as well as the numerous duties incumbent upon the superintendent of an experiment station, it has been out of the question for the superintendent to be away from the station on demonstration and extension work for more than a few hours at a time. It is hoped that arrangements may be made during the ensuing year for members of the staff of the central station to substitute for the superintendent at Glenwood and thus enable him to keep in closer touch with the farmers in the outlying portions of the island.

FORAGE CROPS.

One of the most seriously felt wants of the Glenwood dairy farmer is that of a good, nutritious, milk-producing forage crop that can be successfully grown on the farm, one that will not only satisfy the appetite, as do honohono (*Commelina nudiflora*) and Para grass (*Panicum barbinode*), used extensively under the present system of feeding, but also tend to increase the milk flow and replace a portion of the expensive concentrated ration now being used. Both honohono and Para grass make indifferent growth during the colder season of the year, and a habit of strong winter growth would specially enhance the value of such a feed. Australian water, or Paspalum, grass (*Paspalum dilatatum*) has given greatest promise among the grasses under test at the substation, and it is being planted to a limited extent on some of the local dairy farms. The persistent habits of growth of this species and its natural tenacity of life might, however, render its eradication difficult under existing conditions of continued rainfall. The relation of this grass to forage poisoning of stock in the Southern States as reported upon by Brown and Ranck[1] also suggest a possible source of danger from its general exploitation in Hawaii. The authors of the above-mentioned bulletin advance what appears to be conclusive evidence in support of the theory that certain cases of stock poisoning were due to pasturing on Paspalum grass and find the direct cause in an ergotlike fungus which attacks this grass, existing as a parasite on its pistillate flowers. In view of the serious nature of this malady, it would seem that the live stock interests of Hawaii should be safeguarded by effective and rigorous precautionary measures regulating the importation of Paspalum seed. The possibility that other widely distributed local species of this genus, such as the common Hilo grass (*P. conjugatum*), might also serve as a host plant for this fungus would further emphasize the importance of preventing its introduction.

A few volunteer plants of California bur clover were found to be growing on the substation grounds in December, 1915, and their development during the comparatively cold months from December to April was observed with interest. These plants took possession of a garden plat after it had been thoroughly spaded on December 6, 1915, and made rank and rapid growth until removed on April 11, when the plat was cleared for planting to other crops. The supposition that the seed from which these plants grew was introduced through the medium of imported hay and probably lay in the ground for several months before germinating, combined with the fact that a very heavy crop of seed was nearing maturity when the

[1] Mississippi Sta. Tech. Bul. 6 (1915).

FIG. 1.—GIANT BERMUDA GRASS HAY.

FIG. 2.—VIEW OF EXPERIMENTAL AND DEMONSTRATION PLATS.

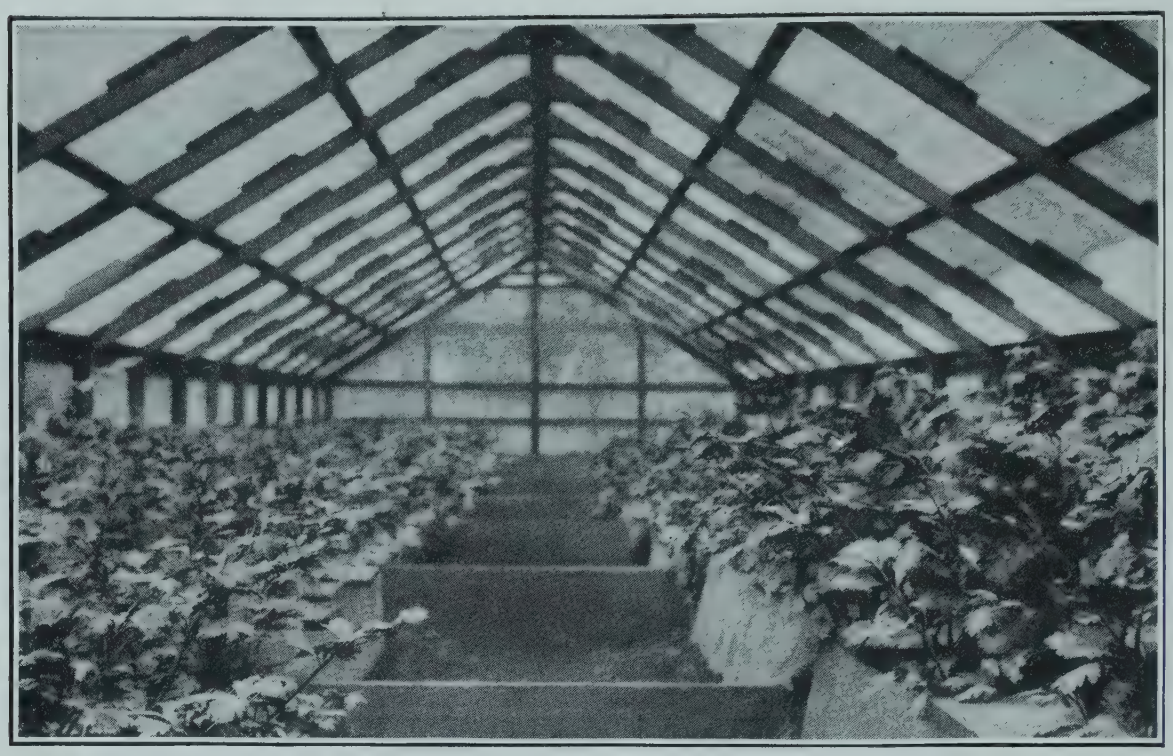

FIG. 1.—CELERY SHELTER HOUSE, GLENWOOD SUBSTATION.

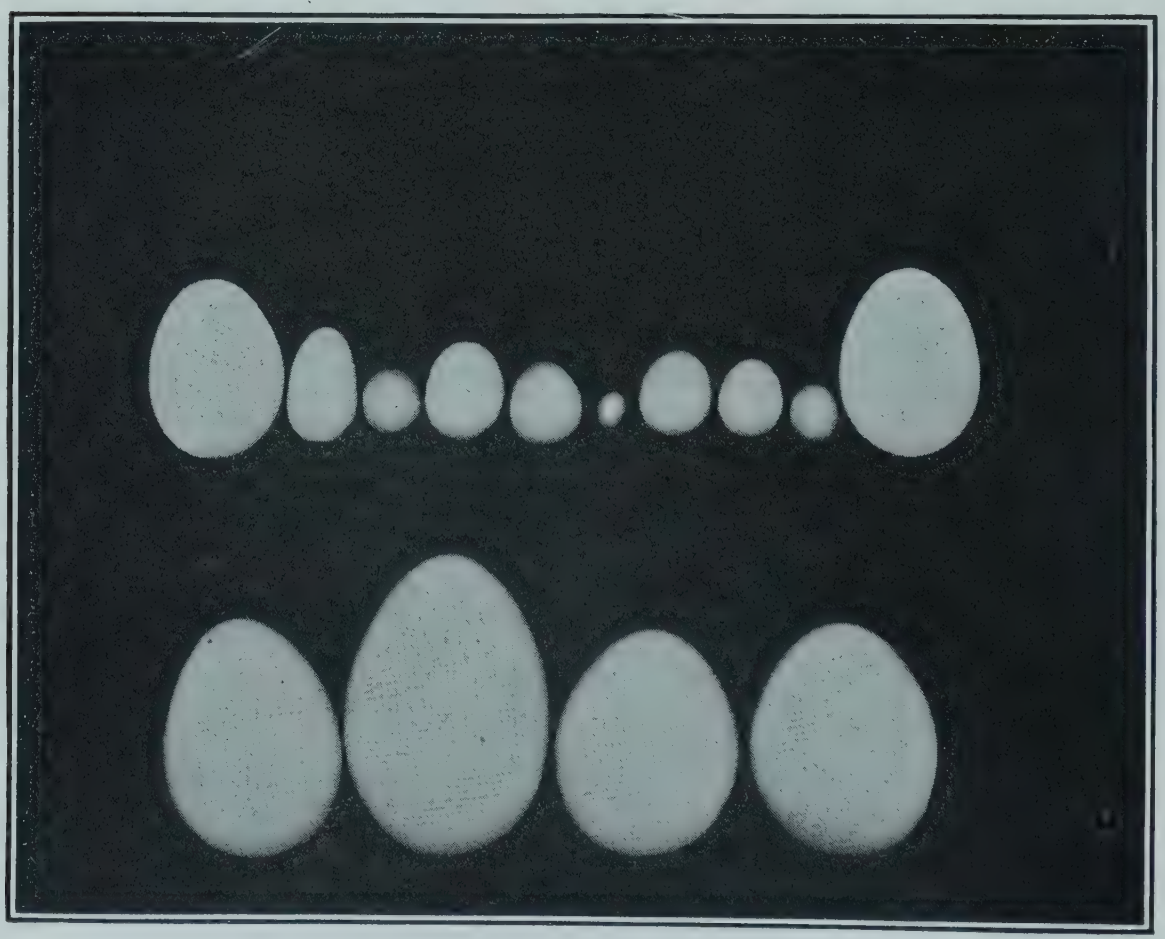

FIG. 2.—CONSECUTIVE EGGS LAID BY PULLETS.

Upper ten eggs laid by pullet No. 112, eight smaller eggs weighing 2¼ ounces. Lower four eggs laid by pullet No. 172.

plants were destroyed, leads to the hope that California bur clover will reseed itself under climatic conditions that obtain in this district. A supply of this seed has been ordered and trial plantings will be made during the coming winter season.

NEED OF A SUITABLE HOG FEED.

In the Glenwood district, where practically the entire homestead population is largely dependent upon the sale of dairy products for a livelihood, a keen interest is shown in the problems of hog production, this industry being a natural adjunct of the dairy, where an excess of skim milk is available in varying quantities throughout the year. A strong deterrent, however, to this alluring feature is the high price of supplementary feed and the lack of any suitable grain crop that is known to be profitable for local production. The substation, in its work for the past few years, has given attention to the problem of supplying a satisfactory feed that will constitute a dependable crop under local farm conditions.

On December 10, 1914, a planting of the edible canna (*Canna edulis*) was made on a measured area of 575 square feet. This was harvested on January 14, 1916, yielding a total of 833 pounds, or at the rate of 31.5 tons per acre. The crop was grown on a plat of good garden soil and the yield was probably considerably greater than would have resulted from plantings made under average field conditions. Another trial was begun on the same plat on January 25, 1916, and on April 5, 1916, a field planting was completed on soil of rather low fertility and without the use of fertilizer. A portion of the product dug on January 14 and kept stored at the substation in ordinary bags for a period of three months showed practically no loss from decay, thus indicating the ease and simplicity with which it can probably be handled in a damp, rainy climate where much loss might be expected. Samples of the fleshy rhizomes of the canna, submitted to the station chemist, showed a composition closely comparable to that of the Irish potato.

In this quest for a local product for hog feed a trial planting of Jerusalem artichokes (*Helianthus tuberosus*) was made during the preceding fiscal year on an area of 960 square feet. This crop was dug on November 5, 1915, yielding a total weight of 490 pounds, or, figured in terms of acre yield, a fraction more than 11 tons. A large portion of this planting failed to grow and the stand was estimated at 33⅓ per cent at the time of harvest. Unlike the edible canna, the Jersusalem artichoke has not kept well in storage, being attacked by a moldlike fungus and completely ruined when stored in bags. In working over the garden plat upon which this crop was grown, a number of roots were found on January 25 in a perfect

state of preservation. These were planted immediately and showed no growth until the first week in May, when a portion of them was found to be sprouting. These observations would suggest the necessity of digging the crop as needed for feed or of allowing the hogs to dig them at will. For general purposes, delayed harvest or a system of stratification would seem to be necessary.

CELERY-DISEASE CONTROL.

By referring to the tabulated meteorological data at the end of this report (p. 43), it will be recognized that marketable money-making crops that will succeed under conditions at Glenwood and its surrounding territory are decidedly limited. The very high precipitation is an unfavorable element, but the low night temperatures constitute an even more decisive factor in the limitations of general crop production. There are few cash-returning crops that thrive under these peculiar climatic conditions. Celery is a notable exception to this rule. There is a constant demand for celery of good quality, and this is being very inadequately met, most of the limited supply being of foreign origin. The one serious problem involved in the production of celery here seems to be the prevalence of late blight, caused by the fungus *Septoria petroselini apii*, and as long as this disease can be controlled, celery grows with unsurpassed luxuriance. The heavy rainfall and the frequency of rainy days preclude efforts to control this disease on unprotected plantings by the usual methods of spraying. During the past year the substation has inaugurated a line of experimental tests in which an effort is being made to produce the crop under shelter, a frame building (see Pl. VI, fig. 1) 72 by 16 feet and covered with cheesecloth having been constructed for these trials. This work has included the disinfection of seed with a weak formalin solution before sowing and the spraying of plants in the usual manner with Bordeaux mixture prepared in accordance with the 5:5:50 formula. At the time of this writing the progress of these trials is encouraging, but maximum efficiency would require complete overhead protection in the construction of which a sufficient amount of glass should be employed to insure an optimum of sunlight.

POULTRY WORK.

The poultry-breeding work being conducted at the substation with the object of increasing both the average number and the average size of eggs through selective breeding has been of unusual interest (Pl. VI, fig. 2). Complete trap-nest and individual egg-weight records have been kept throughout the year. The past season's hatch consists of 212 birds, including both sexes, ranging from two to less than five

months old at the time of this writing. The pullets from the first hatch are just beginning to lay. The greater number of these birds are single-comb White Leghorns from pullet matings. The mothers of these birds were selected from trap-nest and egg-weight records covering a period of approximately four months between the time their first eggs were laid and the beginning of the hatching season. Like records of the entire flock of about 160 birds hatched during the season of 1915 have been kept throughout the year, and the selection of breeders for the past season's hatch, with one or two eliminations and a few additions, will hold for another breeding year. In other words, the selections made from records of the first four months of laying have, in this case, proved generally satisfactory. With the exception of 28 birds, the entire flock of the past year's rearing has been carefully pedigreed and the complete poultry record to date amounts to about 35,000 separate entries.

METEOROLOGICAL RECORDS.

During the past fiscal year the substation has assumed the duties of a cooperative observer for the Hawaiian section of the Climatological Service, United States Weather Bureau, daily records of temperature and rainfall having been taken in this capacity since January 1, 1916. As these climatic factors have an important bearing on general crop production, these data are summarized and presented in the following table:

Summary of meteorological records at Glenwood substation from Jan. 1 to June 30, 1916.

Month.	Absolute temperature.		Mean temperature.		Total precipitation.	Number of rainy days.	Number of clear days.
	Maximum.	Minimum.	Maximum.	Minimum.			
	°F.	°F.	°F.	°F.	*Inches.*		
January	79	47	72.60	54.40	19.99	27	2
February	79	46	74.79	53.55	4.73	17	2
March	80	49	72.51	56.64	17.38	24	3
April	77	53	72.42	57.62	18.50	27	2
May	77	53	72.87	58.00	43.47	29	0
June	74	53	71.37	58.87	17.45	30	0
Six months	.....	.....	72.76	56.51	121.52	154	9

REPORT OF THE TERRITORIAL MARKETING DIVISION.

By A. T. Longley.

During the past year there have been many changes for the better at the division in both organization and equipment, which to a large extent accounts for the heavy increase in the number of consignments

handled as well as in the volume of the sales. The division, after three years of effort, is now in a position to give the producers of the Territory much better service than ever before.

The increased appropriation made by the last Territorial legislature and the new building provided for at the same time have been of the greatest assistance to the division in working up the business of the small producer. The facilities for handling all kinds of farm products are now first class, except that a cold-storage plant for the increasing consignments of dressed meats is yet to be installed. The new quarters are located on Mauna Kea Street, just off Queen Street, and contain offices, salesrooms, rooms for candling eggs, fumigating, dressing poultry, and a garage. There were insufficient funds left after the building was completed to provide for a cold-storage plant as originally planned. As a result a great deal of time is now lost and considerable expense to the producer incurred in putting the dressed meats in local private cold-storage plants.

On July 1, 1915, a branch of the division was opened in San Francisco to facilitate the sale of Hawaiian agricultural products on the mainland, particularly pineapples. During the summer of 1915 pineapple canneries were unable, on account of unsettled market conditions, to take all the fruit offered by the small producers, and, as a great deal of it could not be sold locally, the division endeavored to find a market for the fresh fruit on the mainland. In connection with the establishment of the San Francisco branch and the marketing of pineapples the superintendent made a trip to San Francisco and as far east as Chicago. It was found that the report of high prices paid for pineapples in Chicago was erroneous, and that even though fair prices ruled, the Cuban and Isle of Pines fruit could be placed on the Chicago market in better condition and at $1 a crate less than Hawaiian fruit.

The amount of pineapples offered to the division for shipment to the coast during last season was in excess of the number which could be profitably disposed of there and the mistake of accepting too many was made. The shipments during July, 1915, netted about $8 a ton for the fruit in the field, but when the shipments were increased the returns soon became very unsatisfactory, owing in part to the heavy spoilage en route and in part to the glutting of the market by the heavy shipments of the division and also of private parties in the islands. An attempt was made to relieve the congested condition of the market by sending trial carloads to cities as far east as Denver and Kansas City. The heavy spoilage on these shipments, even though the pines were repacked at San Francisco and the spoiled and spotted fruits removed, was such as to result in severe losses on all these shipments. The spoilage was heaviest when the pines were overcrowded on the steamer without adequate provision for venti-

lation and cooling. During the year a total of 23,532 crates were shipped for which returns have been received. The returns on these were not quite sufficient to cover freight charges, cost of crates, and other marketing expenses.

The quality of produce received by the division is steadily getting better, and shippers are paying more attention to grading and packing. Some producers who are putting up a uniform article are getting higher prices for their products, due to the increased demand for first-class island produce. The marketing of eggs had caused a great deal of trouble heretofore, but since the division established three grades—"selects, "firsts," and "seconds"—the marketing of eggs has been much simpler. "Select" eggs must have the name and address of the producer and his guaranty stamped on each egg. There have been more calls for stamped eggs at 3 cents above the market price than the division has been able to supply.

Practically all the island agricultural products have been represented in the individual consignments received by the division, ranging in size from 1 dozen eggs to 30 carcasses of beef. The consignors were of many nationalities.

Up to January, 1916, no expert accountant had ever gone over the bookkeeping system of the division since it was first put under the supervision of the experiment station in 1913, and as the business was outgrowing the old system, an expert accountant was called in to revise the system and balance the books. The new system has been in operation for six months and is proving satisfactory. In accordance with the new plan, the books are audited each quarter by an expert accountant. Beginning with July 1, 1916, a cost-accounting system is planned for all departments of the business.

To facilitate the handling of small sales to consumers a retail vegetable and fruit department and a retail butcher shop were opened on June 1, 1916. The sales from these departments are practically all for cash, and purchasers are required to take their purchases with them. By this arrangement the cost of bookkeeping and delivery is saved the purchaser.

The establishment of these two new departments reduces the consignment bookkeeping a great deal, for the reason that large quantities of produce are charged to these departments by the consignment department, thus doing away with the many small credits that had to be made when retail sales were made direct from consignments. The returns from the retail branch for the month of June have been very satisfactory, and it is expected that these departments will become self-supporting.

In order to get better prices for the producers on the island of Hawaii, especially in the vicinity of Hilo, the Hawaiian board of

supervisors is considering a proposition to subsidize a branch of the Territorial marketing division in Hilo. Such a branch would be of great assistance in regulating the supply in Hilo and in shipping any surplus produce to Honolulu.

The sales of the division during the past year have increased considerably over previous years, and the cost of marketing produce has been reduced. The sales for the different branches of the business for the year are as follows:

Local consignments (produce received on consignment and sold locally)	$66,977.94
Sales of purchased merchandise (feed, seed, crates, packing material, and produce purchased on the outside to fill orders)	43,087.29
Mainland consignments (all shipments sent to the San Francisco branch to be sold for the account of the division)	17,659.22
Gross total	127,724.45
Less sales from consignment branch to retail branch	6,638.67
Net total	121,085.78

During the coming year the division plans to get in closer touch with producers and their marketing difficulties by having representatives visit their farms and look into local markets. It is planned to keep a more accurate record of what is being produced and when it will be ready for market.

Up to the end of this fiscal year the superintendent, in addition to supervising the work of the division, also attended to many duties as clerk of the experiment station. Being relieved of the latter duties beginning July 1, 1916, he will devote his entire time to the work of the marketing division.

HAWAII AGRICULTURAL EXPERIMENT STATION,
J. M. WESTGATE, Agronomist in Charge,
Honolulu, Hawaii.

Under the supervision of the STATES RELATIONS SERVICE,
Office of Experiment Stations, U. S. Department of Agriculture.

REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION.

1919.

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1920.

HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU.

[Under the supervision of A. C. TRUE, Director of the States Relations Service, United States Department of Agriculture.]

E. W. ALLEN, *Chief of Office of Experiment Stations.*

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LETTER OF TRANSMITTAL.

HAWAII AGRICULTURAL EXPERIMENT STATION,
Honolulu, Hawaii, July 29, 1919.

SIR: I have the honor to transmit herewith and to recommend for publication a report of the Hawaii Agricultural Experiment Station, 1919.

Respectfully,

J. M. WESTGATE,
Agronomist in Charge.

Dr. A. C. TRUE,
Director States Relations Service,
U. S. Department of Agriculture, Washington, D. C.

Publication recommended.
A. C. TRUE, *Director.*

Publication authorized.
E. T. MEREDITH,
Secretary of Agriculture.

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[1] Appointed Apr. 9, 1919, to succeed M. O. Johnson, resigned.
[2] Temporary appointment, Apr. 1 to June 30, 1919.

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REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION, 1919.

SUMMARY OF INVESTIGATIONS.

By J. M. Westgate, *Agronomist in Charge.*

INTRODUCTION.

During the past year the energies of the station were largely directed to the most pressing problems of production of food for human beings and feeds for animals. This work in part was successfully carried out by the distribution of seeds, cuttings, and plants to individuals and to public institutions. Improved varieties were given wide distribution, up-to-date cultural methods, including spraying for insects and fungus enemies, and other means used to increase crop yields, were received and adopted to a gratifying degree by the producers. Pleasant cooperative relationship was maintained with the Territorial food commission, and especially with its corps of county agents.

The station continued to emphasize the desirability of increasing the production of diversified crops. It is and has long been fully realized that locally grown diversified crops must compete, to a large extent, with crops imported from the coast. These are often imported at less expense for freight than is paid on similar crops from the other islands of the group. In Hawaii the uneven surface of the land usually devoted to diversified crops and the small size of fields necessarily increase the amount of hand labor required, thereby increasing the cost of production. It is felt, therefore, that too great stress can not be laid on the desirability of having many new kinds of crops produced in considerable quantities so that the agricultural practices necessary to the production of these crops on a large scale could be readily adopted in case any calamity should befall the sugar, pineapple, or banana industries.

Tendencies in the island seem to have been the nonencouragement, rather than the encouragement, of production of diversified food crops. This fact is borne out by the recent failure of the Territorial legislature to make an appropriation for the continuation of the agricultural county-agent system, and likewise by their withdrawal of the customary appropriation from the Territorial marketing

division. The latter, during the past seven years, developed from a small beginning to where, in April, May, and June of 1919, it handled $56,249.72 worth of produce and filled a long-felt need for the consumer and small producer. At the time that the county agents were eliminated, provision was made for a sugar-cane expert, at a salary of $500 a month, to advise and assist those raising sugar cane on their homesteads. The Territorial financial support was also withdrawn from the Glenwood substation, it being proposed to transfer the agricultural experimental work of the Territory to the opposite side of the island of Hawaii, where there are larger areas of potential homesteading land suitable for the production of diversified crops. An appropriation was made for the establishment and maintenance of a new station at Waimea, Hawaii; unfortunately, however, the money appropriated was to be supplied from the "loan fund," which, it is claimed, can be used for permanent improvements only and not for the operation of an experiment station. At its last session the legislature authorized the expenditure of $5,000 for farm buildings at the Haleakala demonstration farm. It is planned to construct these buildings in 1920, loan funds having been provided for that purpose.

Although the Territorial legislature saw fit to withhold its support from the Territorial county-agent system, it is universally acknowledged throughout the islands that this method, as developed during the war period, thoroughly demonstrated its efficiency in bringing home to the mixed population of the islands those improvements in agricultural practices deemed desirable for general adoption. The personal contact of the county agent with the tiller of the soil is the most effective means of solving the many difficult problems confronted by the producing classes. It is hoped that subsequent Territorial legislatures will reestablish the Territorial county-agent system to supplement the Federal extension work at present under way.

COOPERATIVE ACTIVITIES.

It has been the policy of the station to undertake work in cooperation with individuals, institutions, and organizations, both public and private, wherever the work in question promised to be of mutual advantage. It was felt that by giving careful attention to the formulation and execution of plans, many projects could be as effectively carried out through the cooperation of such an agency as though the station unaided had undertaken the entire work. Such cooperation would make it possible to provide for many more projects than can be cared for when the entire cost of the work is borne by the station alone.

As specific instances, it should be noted that the station continued to cooperate with representatives of the several military posts

throughout the islands, and provided seeds and plants for gardens of the various companies. These gardens, which proved a very valuable adjunct to the needs of the local military establishments, were looked after by specially detailed men from each company, the work usually being assigned to those who showed a decided liking for it. Prizes won at the last two Territorial fairs indicate, in some measure, the success achieved in vegetable raising by the gardeners. The products from each company's garden formed a most welcome addition to the standard Army rations, and, in some instances, the attempts to farm proved so successful that the supply of products obtained exceeded their demand.

The station established an increasing number of cooperative relations with small farmers, and with a number of the larger ranches and plantations. The small grower was provided with such seed and planting material as was found practicable, and all possible information and assistance necessary to further any particular line of his work was furnished him. With larger concerns, the station usually confined its efforts to giving expert advice and assistance in outlining those experiments carried out by the men in charge of the ranch or plantation. Since these experiments sometimes extend over a number of years, those having their immediate oversight must carefully follow them up until the results of a number of seasons have been obtained. It was found, owing to the great diversity in rainfall, altitude, and soil conditions, that experimental results true of one locality may not be true of another, even though separated by only a few miles. For this reason it was desirable to repeat, in the immediate localities where work was to be tried out on a larger scale, those experiments which were successfully carried on by the experiment station. These repetition trials are ordinarily conducted in cooperation with private parties, it not being felt that continual close supervision on the part of the station is as essential as is the case with the regular station experiments.

In addition to the above-mentioned cooperation, the station maintained relations with agricultural societies, chambers of commerce, business men's clubs, and with the trustees of several large estates who are broadly interested in the development of diversified agriculture. The Hawaiian Sugar Planters' Experiment Station, and some of the pineapple, sugar, and banana plantations proved very helpful in a number of cooperative undertakings.

Informal cooperative relations also existed between this and various State experiment stations, and with the several branches of the United States Department of Agriculture at Washington, as well as with the agricultural departments of many foreign countries.

NEED OF SUPPLEMENTARY FOOD CROP INDUSTRIES.

The Hawaiian Islands depend entirely too much upon the sugar industry for their true prosperity, and there is always the possibility that the market price of sugar may fall to such a level that many of the plantations would be forced out of business. There is further a strategic need for the growing of other crops, so that these islands may be less dependent on the outside world for their food. It was, therefore, considered as especially desirable that the development of diversified industry be either in the actual production of food crops or, at least, in the production of agricultural products from which foods can be prepared. In normal times these crops would be available for export either in the raw or manufactured state, and, during a time of blockade or interruption of communication, they could be readily used to feed the local population.

With this end in view, various root and tuber crops were grown for their starch production, and the process of drying and preserving vegetables and fruits received careful attention from many of the station workers. F. G. Krauss, superintendent of the extension division, in company with a representative of one of the local agricultural companies, made a trip of inspection and investigation to the mainland for the purpose of furthering this work and in order to determine market possibilities, methods of manufacture, etc., covering the starch production industry. A large part of the United States was covered, investigations being made in States as widely separated as California, Massachusetts, and Florida. The experiment station and the extension division were primarily interested in this project not only for the above reasons, but because it promises to furnish additional means of livelihood for the small farmer; furthermore, after the starch has been extracted, the residual product can be made to serve as a valuable constituent of mixed feeds for live stock which now depend to a great extent upon imported feeds.

Preliminary investigations made with cassava and edible canna indicate that a profitable industry can be developed. Yields of cassava as high as 16 tons per acre, and of edible canna at the rate of 40 tons per acre, under ideal conditions as to soil fertility and moisture supply, further this possibility when one realizes that about 10 per cent of the edible canna and 25 per cent of cassava is commercially extractible starch. Cassava starch can be used commercially in sizing cotton goods, in the preparation of certain forms of adhesives, and as the source of tapioca. Because of its extraordinarily large starch grains, the edible canna has been declared superior to arrowroot starch for invalids; and it is thought that this product will, as a result, command a price sufficient to make its continued production profitable.

In its further search for additional potential industries, the station devoted some time and attention to the development of methods of manufacturing various fruit and vegetable products, such as dried bananas, pickled fruits and vegetables, guava jelly, vinegar from pineapple waste, candies made up on a foundation of macadamia nuts, and the preservation of the avocado.

THE SECOND ANNUAL TERRITORIAL FAIR.

The success of the first Territorial fair, held in June, 1918, was due in large measure to enthusiasm developed by the war. While the second fair, held in June, 1919, did not receive the same stimulus, very effective work, surpassing that of the previous fair was accomplished by the county agents and other committeemen. The results of the agricultural extension work were manifested in the variety and quality of the agricultural exhibits shown. Among the exhibitors, keen competition was fostered by awarding cash prizes to those who displayed certain crops in which it was desired to arouse interest for their further development.

The second Territorial fair cooperated so splendidly with the experiment station in setting forth the desirability and possibility of diversified crop production that every available resource was temporarily devoted to bringing to a successful close those particular activities for which the station members had been made responsible by the fair commission. Each division of the station was represented by special exhibits, and most of the station staff held one or more committee assignments in connection with the various agricultural features of the fair. Acquaintances made during the food production campaign of the war period were turned by the station to its best advantage in developing enthusiasm among the various exhibitors.

The domestic science exhibits specialized on economical menus rather than on wheat and fat substitutes; the Japanese committee made a most creditable showing of numerous Japanese foods, daily changing its exhibits. The exhibit by the sugar plantations, of various industries which are receiving attention from them, was most commendable. One company exhibited the work of making cement from nonimported materials, and also demonstrated the practicability of obtaining from waste cane molasses a fuel which can be substituted for gasoline. Another plantation made an extensive exhibit covering its development of home-grown feeds for all classes of live stock. Among three exhibitors there was keen competition regarding mixed feeds which contained 50 per cent or more of home-grown products, such as pigeon-pea meal, velvet-bean meal, alfalfa meal, cane-top hay, waste molasses, cracked corn, etc.

HORTICULTURAL INVESTIGATIONS.

One of the more important features of the work of the horticultural division was that of the extension of Macadamia nut growing. About 1,000 seedlings were planted at various elevations throughout the islands. The few isolated old plantings of the Macadamia tree clearly indicate the chances of the successful production of this nut in the Hawaiian Islands.

Work with the avocado made material progress, and it is hoped that a greater interest can be aroused among growers to improve the many varieties of this fruit. Several small cooperative commercial orchards were started mainly to demonstrate the possibilities of the commercial production of the avocado. Sixteen new varieties of the Guatemalan type were received from the United States Department of Agriculture at Washington and planted for observation.

The station not only demonstrated varieties of mango best suited to conditions of the islands, but also started propaganda to further development of the superior strains. As a result numerous seedling trees throughout the islands were top-worked with improved strains, especially the Pirie, upon which the station is concentrating a good deal of attention.

The Solo papaya, which was under test, has proved to be a very promising strain. It has been brought to the fourth generation without deterioration in flavor or other desirable characteristics.

Investigations with the litchi tree were continued, and great prospects are looked for from the propagation of this exquisitely flavored fruit.

Considerable attention was also given to the coffee industry, which, owing to the prevailing low price of the coffee berry, is not in a flourishing condition.

Work with the propagation of pineapple seedlings was uninterrupted, and several thousand young seedlings were planted in commercial pineapple fields of different localities. A few of these are already beginning to bear fruit.

CHEMICAL INVESTIGATIONS.

One of the major projects of the division of chemistry throughout the year was that of drying and preserving Hawaiian vegetables and fruits. By the use of a drier, the working model of which was constructed on the station grounds, various tests were conducted with many island foods which were found adapted to preservation by drying. This drier, which is independent of weather conditions for effective results, is much more rapid in its action than the air drier, which was also kept in operation. By the use

of the small vacuum drier, exact data, showing rate of loss of moisture of the various crops, is readily had. This vacuum drier has also made it possible to obtain a better product of bananas and similar fruits, since the temperature and air pressure can be regulated and determined with much greater exactness than by other methods used.

The drying and preservation of fruits and vegetables, and the production of starch from cassava, edible canna, sweet potatoes, corn, taro, etc., have opened up commercial prospects which are receiving investigation from the experiment station and from various commercial interests of the islands.

AGRICULTURAL EXTENSION WORK.

The extension division, which has kept in close touch with the various agricultural projects of the islands, endeavored at all times to develop the most practical solutions of the many problems continually arising. The headquarters of the superintendent of the extension division are located at Haiku, on the island of Maui. The installation of an efficient telephone service has made it possible for him to keep in touch with the more remote and relatively inaccessible sections of the island.

Lectures, together with voluminous correspondence, and some practical demonstrations of caponizing, home curing of pork, etc., were effective in reaching large numbers of individual farmers. The promising showing made by the pigeon pea, edible canna, and cassava, justified the appeal made by the extension division to increase the production of these crops. Every assistance was rendered home and school garden activities, and some efforts were put forth to include corn clubs, calf clubs, etc., and to further the general development of this work. A pig club was recently launched on the island of Maui, the formal organization taking place in July, 1919, with about 31 enthusiastic young people in attendance. Steps were also taken to establish a farm bureau in each of the leading agricultural sections of the islands.

Nine collaborators were associated with the division during either the whole or a part of the year, one or more being located on each of the five larger islands. During the year the superintendent of the extension division made a trip to the mainland to investigate problems of production, utilization, and marketing of such starch crops as cassava and edible canna, and to determine at first hand the latest development in extension work.

On the island of Hawaii the extension work was materially furthered by the appointment on April 1, 1919, of R. A. Goff as director of extension for that island.

At the Haiku demonstration and experiment farm the best adapted varieties of both new and staple crops were demonstrated, and seed and planting material of these superior varieties were distributed to the farmers throughout the islands.

PLANT-DISEASE INVESTIGATIONS.

The division of plant pathology continued work to develop practical methods for overcoming diseases which infest the standard food crops of the islands. The major portion of the pathologist's time was taken up with investigations of the taro rot and the banana freckle disease. The banana freckle disease, which now threatens the entire industry, is a serious malady which first came under observation in 1917. Experiments carried on in cooperation with one of the leading banana growers resulted in the systematic spraying of a 75-acre field, which is now giving very promising results. An interesting series of observations was made on root rot troubles of bananas, pineapples, and sugar cane. So far these have yielded nothing sufficiently definite to justify publication at this time.

In addition to those reported on in previous annual reports, further miscellaneous plant diseases were observed and recorded.

AGRONOMIC INVESTIGATIONS.

During the year the agronomic activities of the station were concerned primarily with the most practical means of rapidly increasing the production of food and forage crops. This was brought about by the extensive distribution of seeds, cuttings, and tubers to all who had proper facilities for growing them. As soon as it became evident that the end of the war was near, the work of the division gradually shifted from the routine work of stimulating production to the improvement of those crops the standard varieties of which were already very well established throughout the islands.

Both the Guam and the Cuban Red corn have made splendid growth, though the former has given consistently higher yields on the station plats than the latter. However, the Guam variety, because of its white color, is locally at a disadvantage, inasmuch as the market favors a yellow variety of corn. Plans were, therefore, formulated for hybridizing the Guam corn with a variety of the desired color in the hope of combining the leaf-hopper resistant and other good qualities of the Guam corn with the yellow color demanded by the local market. It is considered more practicable to try to change the color of a variety of corn rather than to try to overcome the intense local prejudice of the several races against corn of a shade other than that to which they have long been accustomed.

Experiments with the sweet potato, one of the standard food crops of the island, were carried on to develop strains superior in

yield and possessing excellent market and table qualities. Great variation has already been noted in the seedlings which owe their origin in part to hybridization.

The station plats of edible canna and cassava have clearly demonstrated the value of these two root crops, and liberal distribution of these as planting materials were made. Fertilizer tests have given additional information regarding requirements of these particular crops under island conditions.

The work of the Castner substation was continued and, at the request of the Army authorities at Castner, a planting plan was prepared and submitted for the utilization of the species and varieties found to be most promising. Several days were spent by the agronomist in charge of the experiment station in locating a suitable site on the reservation for planting the more promising varieties on a much larger scale than was practicable at the Castner forage-crop substation.

POULTRY INVESTIGATIONS.

During the latter part of the fiscal year 1919 the station was fortunate in securing the temporary services of a poultry expert, L. M. Ross, who brought to completion a brief survey of poultry conditions in the islands. At present the most pressing problems with poultry are adequate housing, the provision of sanitary surroundings, and the proper methods of feeding, including properly balanced rations. It was found practicable to materially reduce the proportion of imported concentrates in the diet for island-raised poultry. Most of the poultry work of the station was conducted at the Glenwood substation on the island of Hawaii, but the present undertaking shows the need of conducting work on each of the larger islands.

GLENWOOD SUBSTATION.

The work of the Glenwood substation was directed largely to poultry and food crop production. The eggs were used for hatching purposes throughout the islands, and the surplus roosters were made available for breeding purposes. Experiments carried out in the past proved conclusively that potatoes, beans, cabbage, corn, and alfalfa can be successfully produced under Glenwood conditions, but that other standard crops are not ordinarily practicable. Among the successful minor crops were pohas, sorghum, edible canna, and pigeon peas. During the year 12 demonstration plats of alfalfa were established on the eastern side of the island of Hawaii. In many instances where very young seedlings were devastated by cutworms it became necessary to transplant the well-grown seedlings to fields. This was a laborious and expensive undertaking,

but the method will have proved a practicable one if the stands maintain themselves for a number of years.

In addition to attending to his regular duties at the Glenwood substation, the superintendent did considerable extension work in the immediate vicinity of the substation. In this matter it was found practicable to cooperate with the Territorial food commission and its county agents. The district immediately surrounding the Glenwood substation was taken over by the superintendent, who acted as its county agent. The remainder of the island of Hawaii was divided between the two Territorial county agents.

Ever since the establishment of the Glenwood substation the Territory has appropriated most of the money required for its maintenance. The 1919 session of the Territorial legislature, in response to the demand for the establishment of a similar station on the opposite side of the island, transferred its financial support to the prospective Waimea substation. However, it is planned to continue the Glenwood substation without financial support from the Territory, using such Territorial equipment as will not be required at the new station. The Glenwood substation will be run largely as a demonstration station and carry on such experimental work as can be provided from the funds at hand.

CHANGES IN THE STATION STAFF.

During the year there were a number of changes in the station staff. Maxwell O. Johnson, chemist, resigned March 20, 1919, to accept a position as industrial chemist with the Pearl City Fruit Co., Pearl City, Hawaii, at a large increase in salary. He was succeeded by Wallace Macfarlane April 9, 1919. H. L. Chung, assistant in agronomy, was absent in military service from October 15, 1918, to December 10, 1919, inclusive. R. A Goff, superintendent of the Glenwood substation, was appointed extension agent for the island of Hawaii on April 1, 1919. Temporary appointments were given L. M. Ross as poultry expert April 1 to June 30, 1919; E. J. Mooklar, assistant in fruit and vegetable utilization, November 25, 1918, to February 20, 1919; and P. L. Hesketh, assistant in market garden investigations, March 1 to May 31, 1919.

REPORT OF THE HORTICULTURAL DIVISION.

By J. Edgar Higgins.

The activities of the horticultural division were considerably affected during the year by war conditions. James H. Cowan, assistant in horticulture, who left to enter military service, almost immediately upon his return to the station on July 1, 1919, accepted

a position with the College of Hawaii as custodian of grounds. In the meantime no assistant in horticulture has been appointed. P. K. Lee, however, has rendered very valuable assistance in propagation work, in keeping records, in mapping permanent plantings, and in looking after much of the detail work.

While waiting further assistance an attempt was made to sustain, as far as possible, the line of work under way before the war started. Some attention was given to the Macadamia, or Queensland, nut as the basis of a possible new industry; and, on a trip to the island of Hawaii. certain phases of the coffee industry were investigated.

MACADAMIA NUT.

The Macadamia, or Queensland, nut (*Macadamia ternifolia*) (Pl. I, fig. 1), is one of the most promising of all nuts for improvement and for commercial cultivation within the Tropics or subtropics. It has received little attention, however, and in fact has been almost wholly neglected, notwithstanding the fact that it is unexcelled in richness and delicacy of flavor. This is one of the many obscure tropical products which should be brought to light, improved in some respects so as to be better adapted for commercial use, and thus be made to play an important part in feeding the world.

The tree is of upright growth, attains a height of probably 35 feet, has dark green foliage and rather dense head, and begins to bear when from 5 to 8 years of age. The nuts, which are incased in a hard shell one-eighth inch thick, are brown in color and about 1¼ inches in diameter. The kernel is perhaps three-fourths inch in diameter, nearly spherical or slightly flattened, white, and of a delicious flavor. It resembles the Brazil nut but is regarded by many as milder and more pleasing.

The trees of this species vary greatly in respect to productivity, size of nut, character of foliage, and bearing age. This is one of its splendid features, and gives rise to hope for great improvements by selection. One of the first changes brought about should be a softening of the shell, which is hard and thick. This feature probably is highly responsible for the failure of the nut to be more widely recognized and disseminated.

In a letter from Prof. Albert H. Benson, director of fruit culture for the department of agriculture of Queensland, it is stated that the thickness of shell varies considerably among the trees in their native conditions, and his observations have led to the conclusion that had the question of improving this nut been seriously taken in hand a comparatively thin shell would have eventuated ere this.

Another direction for selection and change is suggested by the fact that many of the seedlings have foliage possessing strong, spiny

teeth, while others are nearly free from this objectionable feature. Although the spiny character is not so serious a matter in a nut tree of this nature as in a tree from which the fruits must be gathered by hand, it is important nevertheless to eliminate such an undesirable feature. The spines greatly interfere with the comfort and convenience of the operator when pruning, spraying, and budding.

The experiment station is endeavoring to extend the trial of the Macadamia nut tree for propagation and permanence in Hawaii. This tree was introduced into Hawaii many years ago from Queensland by Messrs. E. W. and R. A. Jordan, the latter of whom secured the seeds in their native land. Specimen trees are to be found to-day in several parts of Honolulu and throughout the islands. The trees have prospered under the conditions in which they have been tried in Honolulu, and a few which bear each year are growing on the experiment station lands on Mount Tantalus, at an elevation of about 1,000 feet.

The division of horticulture grew about 1,000 trees from seeds collected at the Tantalus gardens, and kept them in readiness for planting during the summer of 1918. The station received the hearty cooperation of the trustees of the Bishop estate, and Mr. L. Macfarlane, manager of the Captain Cook Coffee Co., regarding the matter of planting these trees on a considerable scale in Kona. On September 3 a few trees were taken to Kona and later, when arrangements were about completed, a larger shipment was sent. These trees were planted out at different elevations ranging from 600 to 2,100 feet. The soil in which they were placed varies from typical rock land, where only pockets of soil are found, to open friable loam. The trees, which were placed under the care of a large number of tenants of the estate and of the Captain Cook Coffee Co., were in some cases planted adjoining each other so as to increase the probabilities of successful cultivation. The tenants themselves displayed great enthusiasm when learning that the trees were to be planted on their lands. All the trees with only two exceptions were placed among coffee plantings at distances of approximately 30 feet, the distance varying slightly with the method that had been followed in placing the coffee trees. The two exceptions referred to were where the Captain Cook Coffee Co. made plantings of trees 25 feet apart on land especially cleared for the purpose, and also where a few trees were planted in the neighborhood of the company's mill.

About 800 seeds of this species were sown at the station greenhouses in the latter part of the year 1918, and some time during the summer of 1919 the seedlings will be in readiness for transplanting.

THE AVOCADO.

Probably the avocado will always be one of the most important fruits grown in Hawaii. No export industry exists for the reason that the fruit is occasionally infested with the Mediterranean fruit fly, with the result that it is subjected to quarantine upon arrival at the mainland ports of the United States. Demonstration, however, has proved refrigeration to be a most efficient method for destroying the eggs, larvæ, and pupæ of the fly;[3] and, in fact, entomologists claim that this method could be used under careful government control to ship the fruit without danger of carrying the pest to uninfested ports. The following conclusions of Back and Pemberton,[4] reached after exhaustive study of the insect under refrigeration, merit very special consideration in this connection:

> The data contained in this paper show that no eggs or larvæ of the Mediterranean fruit fly survived refrigeration at 40° to 45° F. for seven weeks, at 33° to 40° for three weeks, or at 32° to 33° for two weeks. They may lead to the modification of existing quarantines and encourage the refrigeration of fruit subject to fruit-fly attack. It seems reasonable to conclude that sooner or later the certification of properly refrigerated fruit will be practicable. When an association of fruit growers or a people find it financially worth while there is no reason why they can not operate a central refrigeration plant under the supervision of an official whose reputation shall be sufficient to guarantee all fruits sent out from the plant to be absolutely free from danger as carriers of the Mediterranean fruit fly.

After a large quantity of fruits of uniform grade and variety has been produced to exceed local demands, an export trade to the mainland of the United States and Canada can be developed by the adoption of the refrigeration method. Larger productions of the avocado might result, too, in a trade with New Zealand and Australia and, possibly, without the refrigeration treatment of the fruit, since the Mediterranean fruit fly was well established there many years before it was found in Hawaii. The rapidly developing countries of the Orient must not be forgotten in this connection, for as the East becomes more closely united to the West, the avocado will become as popular there as it is now becoming in the United States. A further use for the avocado will be found in manufactured products. The division of chemistry of this station prepared the fruit in several ways and reported favorably upon a test with the bottled product known as Avocado Cocktail.

There is at present, however, a good demand in the local market for all the really choice avocados—a demand which will increase not only as the population grows, but as varieties and methods of packing are standardized. With this standardization the buyer will no longer have to risk getting unsatisfactory fruit, as now too often happens when he buys, but will know exactly what to expect from his

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[3] Hawaii Sta. Press Bul. 47 (1914).

[4] U. S. Dept. Agr., Jour. Agr. Research, 5 (1916), No. 15, p. 665.

orders. Home consumption of the avocado can be easily increased three or four fold by encouraging the growth of those varieties whose fruits mature between October and May; during these months, the local markets are practically bare, except for some immature fruits which are rushed on the markets to obtain the prevailing high prices.

If the avocado were to be used for the home garden only, the high food value of the fruit and its intrinsic worth would justify all the effort that the station has given it and will continue to give it. In view of the larger possibilities of this fruit, it is to be regretted that even greater attention can not be focused upon it. One of the earliest services undertaken by the station was the adaptation of methods of propagation and the actual dissemination of budded trees which made it possible to establish nursery work on a commercial basis. Several of these small nurseries are now in operation where trees of the choicer varieties can be purchased and where one can engage the services of budders to top-work older trees. The station discontinued the practice of distributing budded trees and propagation is now being confined to some new varieties which are being tested in a few small cooperative orchards. With a view to testing their adaptability to heights, a small orchard of trees was planted at an elevation of about 1,000 feet at the station's gardens on Mount Tantalus.

A number of new varieties of the Guatemalan type were received from the Office of Foreign Seed and Plant Introduction of the United States Department of Agriculture. They represent a part of the valuable collection made by Mr. Wilson Popenoe, agricultural explorer, who spent many months in carefully exploring the highlands of that country in search of the most promising types of the Guatemalan avocado. These are of especial interest to Hawaii, because, like the Guatemalan varieties now grown at the station, their fruits will probably mature in the autumn and winter months when the more common West Indian type is out of season; furthermore, they will probably assist in extending the avocado belt to higher elevations in Hawaii, since they were discovered at altitudes between 4,000 and 6,000 feet above sea level. The new varieties recently introduced into Hawaii and their identification numbers are as follows:

Varieties.	Hawaii Station number.	S. P. I. number.	Varieties.	Hawaii Station number.	S. P. I. number.
Lamat	4246	43476	Benik	4255	44626
Kanola	4247	43560	Mayapan	4256	44680
Ishkal	4248	43602	Manik	4257	45560
Kashlan	4249	43934	Cabnal	4258	44782
Pankay	4250	44785	Cantel	4259	44783
Nabal	4251	44439	Tertch	4260	44856
Nimlich	4252	44440	Ishim	4261	45562
Panchoy	4253	44625	Kanan	4262	45563
Tumin	4254	44627			

FIG. 1.—MACADAMIA NUTS; UNHULLED AND HULLED NUTS AND EXTRACTED KERNELS.

Diameter of plate, 4 inches.

FIG. 2.—THE PIRIE MANGO, A PROMISING VARIETY FOR HAWAII.

Diameter of plate, 10 inches.

THE BEARDSLEY AVOCADO.

Full descriptions of all these are being published in Washington by the Office of Foreign Seed and Plant Introduction, United States Department of Agriculture, and copies will doubtless be available for distribution.

Of each variety, one tree was placed in the small orchard on Mount Tantalus, previously referred to, and others will be planted in different places for trial as they develop.

The Beardsley avocado.—This is a new variety of the Guatemalan type of Hawaiian origin (Pl. II). It is a seedling from the McDonald, one of the two original trees grown from seed first introduced into Hawaii from Guatemala[5] by Admiral Beardsley. Other seeds of the same type are said to have been left at Hilo and probably also on Maui. This new seedling was presented on December 18, 1911, to Mr. L. C. Ables, a careful cultivator who planted it in his home gardens at 1627 Kewalo Street, Honolulu, where the tree now stands. It is known to have produced a crop within four years after planting. The season of maturing the fruit varies, as is the case with all of this type, but it is strictly a fall and winter fruit. The tree is of upright and rather dense habit, a regular and prolific bearer. The fruit is the largest and most perfect of all the Guatemalan varieties that have come under observation at the experiment station. In honor of the benefactor, who introduced the seed of the parent tree, the first of its kind in Hawaii, and who, with much care, maintained their viability this, the best of the progeny that has appeared, has been named the Beardsley.

A description of the fruit in detail by J. H. Cowan, who made the record for the station, is as follows:

> Weight 37 ounces, seed 15½ per cent, rind 13½ per cent, and edible portion 71 per cent. Shape round to pyriform. Fruit cavity, flaring, irregular, rounded, $\frac{5}{16}$ inch deep. Rind, a thick, hard shell of purple color on the surface when ripe. Pulp fine-grained with trace of fiber only at the base. Flavor, rich and nutty. Seed tight in seed cavity.

THE MANGO.

The present is an unusually good year for observations on the mango, as nearly all varieties in the station orchard are now in fruit, and other sorts have been brough in by private growers. A very important factor in mango growing is the wide variation shown by these fruits in their susceptibility to the attacks of the Mediterranean fruit fly. Fortunately, the Pirie, which gives promise of becoming the leading variety of all those introduced, and also some others of the choicer kinds are not attacked by the insect if other more attractive fruits are available.

In view of these facts, it would seem desirable to maintain with the choice varieties of mango, some other more attractive fruit, which

[5] Hawaii Sta. Bul. 25 (1911), p. 43.

would act as a trap in which to catch the flies. The susceptible varieties of mango would serve this purpose so far as diverting the insects is concerned; however, if these varieties are allowed to remain in the orchard, all fallen fruits must be picked up and submerged in water in order that the larvæ and pupæ of the fly may be destroyed. Unfortunately, the mango has been found not adapted to the several species of parasites introduced to destroy the Mediterranean fruit fly. According to Pemberton and Willard,[6] parasitism of fruit flies in the mango falls at times as low as 7 per cent of the total number of insects taken from the fruit during an entire month, while the average is uniformly low in the fruit. In coffee, which is a favorite fruit for the fly, there is a high percentage of fruit fly parasitism, running as high at times as 94 per cent. Were a variety of coffee to be found which ripens its fruits during the mango season, this could serve not only to protect the immediate crops, but also to greatly increase the number of parasites and reduce the fly. As above stated, there is in many localities a considerable assortment of fruit more attractive to the fly than the Pirie and some other varieties of mango. This interrelation of fruits, pest, and parasites should be kept in mind as it may frequently be found desirable to plant or graft in some fruit for the protection of the Pirie and of other choice varieties of mango.

The mango seed weevil (*Cryptorhynchus mangiferæ*) has become a very prevalent pest. Fortunately, it remains within the husk of the seed until some time after the fuit has ripened, and does not pollute the flesh of the mango or detract from its external appearance. Nevertheless, its presence within the seed often affects the appearance and even the flavor of a portion of the flesh surrounding the seed. In the case of the Pirie and some other good varieties, this injury is very slight unless the fruit is allowed to become overripe. The greatest injury is done to the seed, which, if allowed to remain within the husk, is usually destroyed. It is estimated that about 90 per cent of all the seeds opened at the experiment station this season were weevil infested and, therefore, unfit for propagation.

Various means are being tried to save the seeds from complete destruction. One of these consists in cutting open the husk as soon as it can be cleaned and slightly dried. When wet the husk is extremely difficult to cut, but when dried for about one day, it can be cut at the lower end at a point corresponding to the stigmatic point of the fruit; this cut may be extended up the ventral edge of the seed so as to permit the entrance of the thumb of each hand, with which the husk may be pried open and the seed removed. If the seed is found to be weevil infested, but not yet fully destroyed, the insects can be killed, the seed cleaned, and then planted. If the embryos of the seeds, many of which are polyembryonic, have been

[6] Jour. Agr. Research [U. S.], 12 (1918), No. 2, p. 106; 14 (1918), No. 13, p. 607.

destroyed, the seed will be useless, but should one or more of these remain uninjured, the seed can be expected to grow. Seeds planted without the husk require on an average 18 days to germinate, while those planted with the husk require on an average about 40 days to germinate.[7] It should be remembered that the only way to distinguish unsound seed is to open it. If such a seed were planted without having been opened, the long period required for germination would suffice for its utter destruction by the weevil within.

When a large percentage of the seeds has been found to be injured beyond the possibility of recovery, the removal of the seeds from the husks becomes a somewhat expensive though very necessary means of securing seedling plants. A less expensive, but less effective, method tried for the destruction of the insect consisted in making one rapid cut at the lower end of the seed as described above, after which the seeds were placed in a sack and submerged in water for one hour. Seeds so cut were also fumigated and, the weevil, which manifests a high degree of resistance, killed. The seed when cut open is moist within, but determination has not been made as to whether it can endure as much fumigation as the weevil will, or whether the frass or refuse created by the weevil will contribute to the decay of the injured seed.

MANGO VARIETIES.

This season has offered excellent opportunity not only for noting the local adaptability and characteristics of the mango varieties, but for establishing the synonymy of certain names. Lack of space prevents a detailed pomological description of each variety, but a few notes will serve to record the outstanding features of a number of them and to indicate those which seem best adapted to local cultivation or which are of most interest from the standpoint of breeding.

Pirie (Pl. I, fig. 2).—This variety is considered the best, at least for lowland conditions, of all the mangoes that have been introduced into Hawaii. It is of medium size, inclining to the rounded form, with a distinct beak at the stigmatic point. The surface is smooth and, when ripe, is a pale yellow beautifully marked with crimson where exposed to the sun. It is practically fiber-free, has a delightful aroma, and is as soft and juicy as a ripe peach. The seed is easily removed, so that the fruit can be served in halves and be eaten with a spoon without the slightest inconvenience. In order to remove the seed, it is only necessary to make a cut circling the fruit, about midway its length, and extending as deep as the surface of the seed. Then, by a slight twisting motion, one half of the fruit can be separated from the seed, leaving a smooth, unbroken surface within. By cut-

[7] Hawaii Sta. Bul. 12 (1906), p. 10.

ting very slightly around the seed, it may easily be removed from the remaining half of the mango. The flavor is so unusually delicious as to put this mango in a class of its own in Hawaii. The Pirie is less subject than other varieties to the black spots caused by the fungus *Colletotrichum glœosporioides*, and, while not immune to the fruit fly attacks, it either possesses a high degree of resistance, or is not a preferred variety for the fly. No injured fruits were found in this variety in the station orchards this season, though crops of several of the other varieties were rendered almost worthless.

Kavasji-Patel (*Cowasjee-Patel*).—This is one of the largest of the Indian mangoes introduced into Hawaii, being excelled in average weight only by the Sundersha. It inclines to the rounded form, is somewhat depressed on the ventral surface, and in color is pale green, which turns to yellow as the fruit ripens. The texture is excellent, but the flavor is somewhat inferior to that of the Pirie. The tree makes vigorous growth, but is a shy bearer.

Jamshedi.—This is a mango of large size approaching more nearly the spherical shape than most mangoes. It is of green color even when ripe, and has a good flavor and texture. The chief weakness of the variety seems to be its lack of attractiveness in color. The tree is a free bearer.

Mullgoa.—The Mullgoa is a large variety closely resembling Jamshedi, but distinguished from the latter variety by the large pale green spots which appear on the fruit.

Mulgoba.—This variety, which has proved so popular in Florida, has not attained prominence in Hawaii. The fruit is of medium size, being about the same in this respect as the Pirie. It is of good flavor and texture and is golden yellow when ripe, often splashed on the shoulder with red. The name has been considered by some as a probable synonym of Mullgoa, but it is a wholly different fruit, much more yellow and elongated.

Strawberry.—The tree, received under this name from India through the Office of Foreign Seed and Plant Introduction of the United States Department of Agriculture (S. P. I. No. 10643) seems to be identical with Pirie.

Peter's No. 1.—The variety received under this name fromTrinidad, through the Office of Foreign Seed and Plant Introduction (S. P. I. No. 3706) also appears to be identical with Pirie. Doubtless the name is a more recent one than that of Pirie, which is an old established East Indian name.

Alphonse.—This variety has attained great fame in India, but, because of its lack of flavor, it has failed to become popular in Hawaii. It is of medium size and quite distinct in shape, being flattened on the ventral surface and without any prominent stigmatic point. The

Alphonse is indeed a handsome mango, being golden yellow in color and beautifully marked with crimson on the shoulder.

Hafu.—The Hafu is apparently a synonym of Alphonse.

Douglas Bennett's Alphonse.—Up to the present no consistent points of difference have been distinguished at the station between this variety and those received under the name "Hafu" and "Alphonse." However, a closer study of a large number of trees may reveal points of difference.

Ameeri.—The variety known as Ameeri is probably the most magnificently colored of all the mangoes introduced into Hawaii. It is elongated in shape and rather symmetrical, the exposed side being overlaid with a purplish hue, which changes to a gorgeous crimson on ripening, while its unexposed surface turns yellow. This mango is of good texture and fairly good flavor. The tree is vigorous and a good bearer. Because of its remarkable coloring, the Ameeri is well worth growing as an ornamental and should be of special interest to any plant breeder who desires to combine these color characters with the flavor or other desired characters of Pirie, which, though beautifully marked, has coloring less striking.

Brindabani.—The most prolific of all the mangoes that have been introduced is the Brindabani. The trees have been regular and abundant bearers, apparently devoting all their energies to the production of fruit. After they attain the bearing age they do not make rapid vegetative growth, though in healthy condition. The fruit, which is rather small and quite round, is green, the exposed surface being overlaid with dull brown or reddish tints. The flavor and texture can hardly be rated higher than fair, but it has the advantage of maturing very late, after most varieties have passed their season, and it is probably as nearly immune to the fruit-fly as any mango in Hawaii.

Totafari.—The Totafari is a handsome bright yellow mango, somewhat large, elongated, and rather symmetrical, with a prominent stigmatic point. It is of good texture, decidedly acid flavor, a reasonably good bearer, but quite susceptible to fruit-fly attacks.

Sundersha.—This is perhaps the largest mango in Hawaii. Its shape, which makes it unfavorable as a commercial mango, is very distinctly that of the letter S found also in the No. 9 mango quite familiarly known in these islands. The Sundersha is well colored and altogether a handsome mango, though not equal in flavor to some of the other varieties.

Divine.—This, the most inappropriately named of all mangoes, if judged by its performance in Hawaii, is of small size, extremely subject to the black spot disease referred to elsewhere, rather green in color, and well marked with red on the shoulder where not injured

by the disease. The flesh, which possesses only a fair flavor, is highly colored, of fair texture, and surrounds a rather large seed.

Cambodiana.—Cambodiana is of an entirely different type from any of the true Indian mangoes. It was received by the Office of Foreign Seed and Plant Introduction from Saigon, Cochin China, and is regarded by some botanists as a distinct species, to which has been given the name *Mangifera cambodiana.* Evidently to this type belong the numerous seedling varieties which have long been known in Hawaii under the name Chutney mangoes, sometimes spoken of as Chinese mangoes. All of these possess a distinct aroma, the foliage having a peculiar odor and a characteristic color and shape which distinguishes this type from the Indian varieties. The fruit of the Cambodiana is of medium size, beautiful golden yellow in color, and possesses a delightful subacid flavor in the highly colored flesh, which is of good texture and fiber free.

Wootten.—The Wootten is a variety of local origin belonging evidently to the Cambodiana type or to a cross between this and some variety of the Indian type. It is of medium to large size, of golden yellow color, slightly touched with red on the exposed shoulder, of good texture and rich flavor. One of the most important features of the Wootten, which permits its being marketed in an attractive condition, is the fact that the fruit remains hard while developing a remarkably good coloring. Some otherwise excellent mangoes fail to develop a good color until they are quite ripe.

Smith.—The Smith is another variety of local seedling origin and of the Cambodiana type. It closely resembles the Wootten, but it is earlier, of smaller size, and a little more highly colored on the exposed shoulder.

Number 9.—This is a variety, or perhaps more properly a type, introduced under this name many years ago by the government of the Hawaiian Islands. Many seedlings of it have appeared, most of them rather closely resembling the original type introduced. Practically all of these incline to the letter S shape, are very juicy, fibrous, and not highly flavored. The trees are abundant bearers, make vigorous growth, and produce handsome fruit rather free from the black spot disease.

Victoria.—The Victoria is a very beautifully colored variety of the No. 9 type grown by Mr. T. G. Thrum, Thurston Avenue, Honolulu.

Hawaiian Sweet.—This is more probably a type than a variety. It was the first mango, and among the early acquisitions of foreign fruits, introduced into the Hawaiian Islands, and was probably brought here by the late Don Marin. Few of its many seedling varieties, all closely resembling each other in shape and flavor, have been considered worthy of propagation by grafting or budding.

Oahu.—Probably the only seedling of the Hawaiian Sweet mango that has proved sufficiently distinct and valuable to cause it to be given a name and to be propagated by grafting is the Oahu. This remarkably handsome mango is large, possesses a mild and sweet flavor with abundant juice and has better texture than the average of its class. Many of the fruits show a tendency to be seedless, their husk containing no seed. This character, however, is not constant.

THE TOP-GRAFTING OF MANGO TREES.

Earlier reports and bulletins of the station described methods developed for the top-working of mango trees. Hawaii, however, is not a country of orchardists, and these methods were not applied as widely as they might have been had there been available someone who could be employed to do such work. The station, therefore, undertook, about two years ago, to forward this movement by detailing to the work on part time a man who had long been in training here. As the work developed, there appeared to be a large opening for an expert propagator in this and similar lines. The station, desiring to relinquish its operations as soon as assured that the work would be continued independently, and that owners of trees could get an experienced propagator to graft them, withdrew, leaving the work to be carried on as a private business by two men. In order to disseminate choice kinds of fruit the station supplies scions of the best varieties to these men or to any others who desire them. One of the most progressive of the large sugar plantations planted several hundred seedling mangoes along its avenue, and is having them grafted with choice East Indian varieties.

The very excellent crop of the Pirie variety this season made it possible to bring this fruit to the attention of the people by exhibitions which were held in prominent places in the city; and, at a luncheon given by the Honolulu Ad Club, its excellent qualities were demonstrated. This club has appointed a committee to aid in forwarding the movement for better mangoes in Hawaii, by means of substituting the Pirie and other choice varieties for the many inferior seedlings. As soon as the merits of these more recently introduced varieties become widely recognized, there will be a general movement to produce the best; the Territory will then be supplied, as it ought to be, with mangoes of real merit, and, should the quarantine regulations undergo changes suggested by Back and Pemberton in their above-mentioned discussion of the avocado, the exporting of mangoes may very easily become an important industry.

The station this season is conducting experiments in canning and drying the Pirie, and should either of these methods prove successful in producing a preserve which approaches the excellence of the

fresh fruit, an industry of very large possibilities would undoubtedly be developed.

THE SOLO PAPAYA.

This variety of papaya (Pl. III, fig. 1) which has been under cultivation through four generations, has transmitted its characteristic flavor and texture, and to a reasonable degree its shape, in all of the plants of its kind that have come under observation. To this variety has been given the name "Solo." It is quite small, in some instances the fruits permitting of only one serving; in others, the fruit is large enough for two servings. Most plants of the variety are hermaphrodite or bisexual, but a staminate tree is found occasionally. Although the fruits are small, they are crowded into the axil of nearly every leaf and are so numerous that the yield is reasonably heavy, yet not equalling in weight that of some of the large kinds. The fruit is pyriform, somewhat irregular, colors well and uniformly before softening, and is free from the diseased spots which attack the surface and penetrate the pulp of many of the large forms, The flesh is of medium thickness, of bright yellow color, smooth. tender almost to melting, and of delicious flavor even near the stem end where many papayas lack flavor. The seeds, which are abundant, permit of ready and rapid means of propagation, and, because of the loose placenta or inner lining of the fruit to which the seeds are attached, they are very easily removed when preparing the fruit for serving. From the standpoint of the home gardener, the Solo is considered one of the best of the papayas that have been grown at the experiment station, for, although small, its qualities of texture and flavor give it first rank. The Solo can be used as an individual fruit.

This variety is being quite widely disseminated throughout the Territory by the distribution of seeds and seedling plants. Several other kinds of papayas, under selection for several years, were also sent out in rather large quantities. The purpose of this distribution was to establish the best varieties in as many places in Hawaii as feasible, and also in other parts of the Tropics. Nearly every mail brings requests for seeds of the Hawaii Station selections. In general, it is possible to assign to each applicant only a limited quantity for trial and further propagation, but on one or two occasions where a hurricane had destroyed much of the vegetation, as was the case in the island of Guam, several pounds of seed were sent. In one or two cases, cooperative plantings were made where it was possible to keep them under close observation.

FIG. 1.—THE SOLO PAPAYA. LENGTH OF FRUIT 6 INCHES.

FIG. 2.—TRUNK OF LITCHI TREE BROKEN OFF JUST BENEATH SURFACE OF SOIL, SHOWING (*a*) DEAD STUB OF LAYERED BRANCH.

FIG. 1.—LONGAN TREE SHOWING INHERENT WEAKNESS IN STRUCTURE DUE TO MANNER OF ATTACHMENT OF BRANCHES.

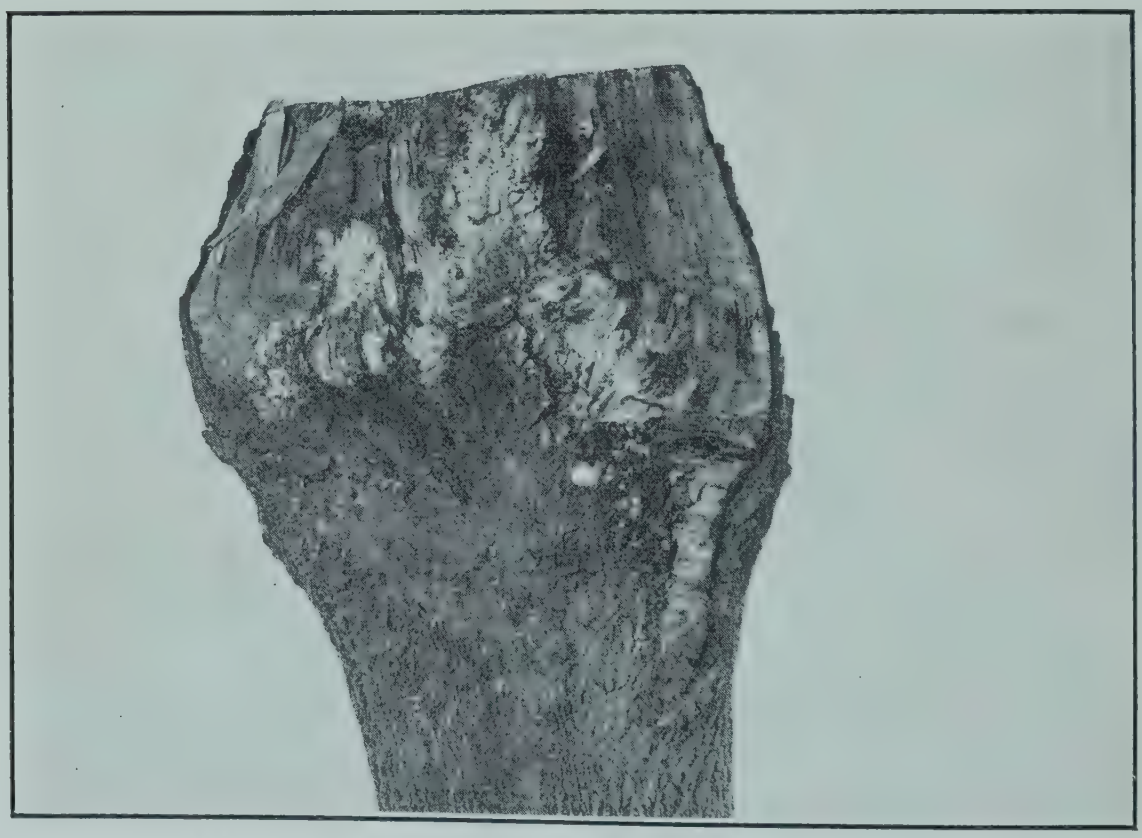

FIG. 2.—BRANCH BROKEN FROM TREE FIGURED ABOVE, SHOWING MEAGER ATTACHMENT.

THE LITCHI.

It has not been possible to extend the investigations of the litchi as rapidly as was desired. The propagation of the varieties in the station collection is being continued. In the latter part of May, 1917, G. Weidman Groff, professor of agriculture in the Canton Christian College, Canton, China, arrived at Honolulu en route to Washington, D. C., bringing with him certain varieties of litchi plants intended for the Office of Foreign Seed and Plant Introduction of the United States Department of Agriculture. These varieties did not endure the journey well, and it was feared that a further trip of 5,000 miles would result in their total loss. The plants were, therefore, left in the care of this station where it was possible to restore to a growing condition the following varieties: Waai Chi, Kwei Mei, San Hing Heung Lai, Saam Uet Hung, Haak Ip, and T'in Naam. It was possible to cooperate with the Office of Foreign Seed and Plant Introduction also in aiding the further trial of the litchi in Florida by shipping to Washington in June, 1918, 25 pounds of fruit to be used for further propagating this species.

It is well known that the customary method of propagating the best varieties of litchi is that known as Chinese, or air-layering. This consists essentially in the removal of a ring of bark from a branch, and surrounding the wound with soil or moss which is kept constantly moist until root formation takes place from the upper or outer side of the wound. It is, however, questionable whether such a root system is ever as satisfactory as that produced from the growth of a seed. Plate III, figure 2, shows the stump of a litchi tree broken off just beneath the soil by the storm which occurred early in December, 1918. In the center of the wound may be seen, at the point *a*, the remains of the old branch which was layered to produce the new tree. This small piece of dead wood was simply the remains of the old branch from which the bark had been removed, and was of no service to the new tree after it extended downward beyond the root system. It will be seen that the root system was apparently very meager, although this tree had reached a height of 10 or 15 feet. Further observation disclosed the fact that the grain of wood at the point of junction between the roots and the stem was hardly favorable to strength of structure. It is often noticed when taking young litchi layers from a parent tree that only one or two good roots have formed. It is problematical whether further roots grow except those which serve as an extension and amplification for the roots present when the layer is taken from the tree. Whether or not an exhaustive study has been made of the root systems of air-layered litchi trees is unknown to the writer. It was pointed out in

an earlier publication [8] that the system of air-layering is likely to be superseded by the budding or grafting of the litchi on seedling stocks of its own, or of some closely allied species. Present observations on the root systems of an air-layered tree, suggest a further possible reason for developing other methods of propagation than that commonly practiced in the land of the litchi. In Bulletin 44, above referred to, reference was made to the temporary success of grafting the litchi on the longan. For more than a year these grafts remained in a flourishing condition, but later a peculiar condition developed which resulted in the failure of all the trees. This failure was attributed to incapability on the part of the litchi growth to sustain the longan stock upon which it was placed. Shoots were sent out by the longan, but these were persistently removed to encourage the growth of the litchi. In some instances large swellings were thrown out by the litchi branches, some distance above the point of union, suggesting the possible backing up or concentration of material at these points. Prof. Wilbur MacNeil, of the Oahu College in Honolulu, grafted scions of the litchi from this station into one or two branches in the top of a longan tree in his garden. This work was done at the time when the station trees gave promise of success. These branches continue to grow in the top of the tree surrounded by longan branches, a fact which bears out the theory that incompatibility between the stock and the scion is due to inability of the scion to nourish the stock.

The structure of the longan tree.—Attention is herein directed to certain observations on the structure of the longan tree. Although this species does not at present give great promise as a stock for the litchi, it is well worthy of cultivation for its own fruits. Plate IV, figures 1 and 2, shows the manner of attachment of the branches of the longan, and also a large wound caused by the breaking off of a branch under the stress of wind. A careful study of the attachment of the two remaining branches shown, and of the wound, will prove inherent weakness in the manner of attachment of the branches. It will also be seen from the wounded surface of the removed branch, as well as from the wound on the remaining branch, that there was practically no attachment above the point where the grain in the branch was parallel with the grain in the remaining limb. These observations point to the importance, when pruning, of selecting branches of the best possible attachment for the formation of the main framework of the tree and of the early elimination of branches that are very poorly attached.

[8] Hawaii Sta. Bul. 44 (1917), pp. 10, 11.

COFFEE.

In September, 1918, the horticulturist made a trip to the island of Hawaii for the purpose of investigating certain phases of the coffee industry of that island, especially regarding its status, its needs, both from an agricultural and from an economic point of view, and the availability of some of the by-products of coffee culture as possible sources of caffein.

As an introduction to notes relating to coffee, there is herewith submitted a brief review of the system now commonly used in coffee growing in Hawaii, and the process of preparing it for market, which perhaps may make more clear certain statements relating to by-products and also to the present conditions of the industry. Coffee is grown in Hawaii chiefly on the tenant-farm system. In the Hamakua district there is one large plantation which is cultivated by the owners with employed labor. This plan may be carried out to a limited degree by some planters in Kona, but for the most part the lands, in lots varying from 5 to 25 acres, are leased to small growers. In many instances, these lands are leased from the owners by coffee companies, these in turn subleasing them to others. A large part of the crop, while still in the cherry, is sold to the mills. A considerable portion also is pulped and dried by individual owners on small drying floors and later sold in the form of parchment coffee. The pulping is sometimes done by a small machine in a given locality for a small charge, when the coffee is returned to the owner for drying. The small growers do not attempt to remove the parchment, because the machinery required for this process is somewhat expensive, and some large growers prefer to hire this service rather than install the machinery for the work.

In Hawaii the process of preparing coffee for market is the one commonly employed for washed coffee. After it is picked, the coffee cherry is taken to the pulpers as promptly as possible, though it does sometimes remain in the bags for two days or more. It is then passed through the pulping machinery which separates the seed from pulp. The small machines consist of a roller having a rough surface. To secure a rough surface, the roller is sometimes covered with a sheet of brass through which holes have been made from the under surface. The heavier machine used in the mills consists of series of three or four rollers, the first of which crush and separate the larger fruits, and the later ones the smaller. The pulp is carried away by hand or by automatic carriers to a convenient place where it is allowed to ferment. After fermentation takes place, the pulp is used for fertilizer, and in the larger mills it is used in part for fuel. The coffee seed as it is separated from the pulp is covered with a sweet gelatinous substance which must be removed before the coffee can

be properly washed and dried. To facilitate its removal, the wet coffee passes to fermentation tanks where it is allowed to remain for 24 hours or more, after which it can be washed. In the larger mills there are revolving washing machines which churn the coffee with water and remove the gelatinous cover. The cleansed seed is then taken by automatic carriers, or, in the case of a small grower, by hand, to the drying floors where it is spread out for the first drying. Every precaution is taken to prevent rain from falling upon the beans. From time to time, as necessary, the seed is turned and stirred so as to prevent musting, and to hasten drying. At the mills, after the free water has been eliminated, by the first drying process, the coffee is taken by automatic carriers into the mill for more complete artificial drying, various devices being used for this purpose. When sufficiently dried, either by natural or artificial methods, it is ready for sale as parchment coffee. The outer husk or parchment-like cover is then removed, and the thin, soft covering, known as the silver skin, or waste material is separated from the cleansed coffee bean. The best machinery also grades the beans according to size, after which damaged beans are removed by hand from the best grains. On a large table, which is divided into compartments or bins, the beans are usually spread out sufficiently to make it possible to quickly find and remove the undesirable ones. In one mill at least, where machinery used for this process is under the control of the operator, a movable-belt table passes toward him, carrying a small quantity of coffee beans from which damaged specimens are picked out by hand. It is chiefly in this form that most Hawaiian coffee is marketed for export trade, though roasting, grinding, and packing are used to a limited degree.

Present status of the coffee industry.—The coffee industry in Hawaii, in addition to struggling for many years against competition with imported coffees grown on cheap land by low-priced labor, was, as a direct outcome of the war, completely cut off from many of the large markets of the world; prices dropped so low that coffee growers received less than in prewar times, and the cost of production was necessarily increased by the rise in the price of labor. Still more serious was the rise in the price of commodities which coffee growers need for their maintenance. Many of the growers are of oriental descent, and rice is their staple food. As one of the growers stated the condition: "Before the war three bags of coffee cherry would buy one bag of Japanese rice. Now it requires eight bags of cherry to buy one bag of rice." Rice advanced from $5 to $6 per bag to about $13, and coffee cherry fell from over $2 per bag to $1.65. While the American farmer on the mainland paid high prices for certain commodities, he received in return large prices for his agricultural pro-

ducts. The tide for the Hawaii coffee growers on the other hand was against him both in the price of production and distribution.

At the time of the present writing, June, 1919, the price of coffee has advanced to a price which breaks all recent records. This is, no doubt, due in great part to conditions brought about by cessation of war and the reopening of European markets, and perhaps also to frosts which are reported to have occurred in some of the coffee producing areas of Brazil. This rise in price probably came too late in the season to prove of immediate benefit to the producers, the sale of their crop being generally arranged in advance of the harvest season, or very soon thereafter because of shortage of funds. Should these high prices prevail through another harvesting period, coffee growers may expect to profit by the advance. Since, however, these prices can not be expected when normal conditions are restored, everything possible in the meantime should be done to assist this struggling industry of Hawaii.

Agricultural needs of the coffee industry.—Some years ago the green scale, *Coccus viridis*, menaced the industry; this pest is now however controlled by natural enemies. From an agricultural point of view there is no reason why the coffee business might not be greatly extended and it doubtless would expand rapidly were economic conditions to change in its favor. There is need, however, for experimental work along many lines. In Kona, one of the leading districts, no shade has been used on most of the plantings. Many of the trees have suffered no doubt for want of shade, but only after careful trial can it be determined where and under what conditions shade trees are needed, and what trees are best adapted to this purpose. The experiment station used a few trees of the *Inga laurina*, which were planted for trial by the Captain Cook Coffee Co., while the silver oak (*Grevillea robusta*), kukui (*Aleurites moluccana*), and others were tried to some extent by others. Very careful investigation, however, should be given the subject of shading so that definite data will be available.

Pruning of coffee trees in Kona, Hawaii.—In Kona no very definite method of pruning coffee trees is practiced by most growers. Pruning experiments are needed to determine their relation to shade, to varying distances required for planting, to ascertain individual differences in trees, and also to discover their relation to prolonging the life and increasing the productivity of the trees. The trees were planted at distances varying from 4 or 5 to 10 feet apart; the tendency appears to have been that of too close planting. Another matter needing immediate attention is that relating to proper distances in planting. Many of the older trees, where planted very close, have grown to great height for light and air and practically their only

bearing surface is on top. Only a small bearing surface has been the result, therefore, despite the fact that a large number of trees were planted to the acre. Some experiments might be well worth while in order to determine whether it would be practicable to restore these old trees to health and productivity by some renewal system. Fertilizer experiments are also needed in order to determine their most effective and economical use.

Another promising field for experiment would be to select trees of unusual vigor and productivity and propagate them by asexual methods so as to develop greater uniformity. These methods of propagation might also prove of value in top-working old plantings to a superior strain. At present there are only two recognized commercially grown varieties in Hawaii, one known as the Hawaiian coffee, the progeny probably of a very early introduction, and the other the Guatemalan, which was introduced 20 or 30 years ago during a time when coffee growing was prospering.

Budding and grafting experiments.—Certain simple trials in budding and grafting, along the lines just indicated, were undertaken by the writer during a brief stay in Kona. Mr. L. Macfarlane, manager of the Captain Cook Coffee Co., called attention to a few trees of the Maragogipe variety of coffee grown for trial from seeds introduced by him some years ago. This variety of coffee was discovered in Brazil about 1870. It produces a large berry and large bean, commands fancy prices and is well worth very careful trial in Hawaii. Mr. Macfarlane secured the variety in Mexico, where it is grown to some extent. Buds from this variety were inserted on the main stem of some 2-year-old trees, and also on a few suckers in the upright-growing branches of older trees. Scions were also taken from this variety and were inserted as cleft grafts and also as bark grafts on the main stem of 2-year-old trees and also on the large upright growths of older trees. Coffee trees make two distinct forms of growth, the upright and the lateral. It has been found that coffee buds taken from the lateral growths continue to produce lateral growth in the new trees on which they are placed, and it is only by the use of the dormant buds subtending laterals on upright growths that it is possible to secure a normal upright budded or grafted tree. A letter from Mr. Macfarlane concerning the outcome of this work, which was performed shortly before leaving Kona, indicates that the budding was quite successful on the younger trees but on the older stocks grafting succeeded better than budding. However, the work was on too small a scale to justify any general conclusions as to the best methods of propagation, and should be regarded as preliminary to further experiments which may be carried on.

Coffee by-products.—In a letter from the Chief of Insular Stations, States Relations Service, United States Department of Agriculture,

it was requested that the practicability of recovering the caffein in coffee pulp, prunings, etc., be investigated in Hawaii. The following extract of a letter from Dr. Frederick B. Power, pharmaceutical research chemist in charge of Phytochemical Laboratory of the Bureau of Chemistry, United States Department of Agriculture, presents the problem:

> This laboratory has for some time been interested in the question of the utilization of sources of caffein other than those heretofore employed. A preliminary examination of coffee leaves and coffee pulp obtained from Porto Rico have shown that they both contain appreciable amounts of caffein. It would be of interest to us to know to what extent such material would be available and at what period of the year the leaves and pulp could be obtained.

An investigation was made in Kona and in east Hawaii to determine the amount of such materials as might be used in this way, and also their present uses and the possibility of their availability for the proposed purposes. These two districts comprise nearly all the coffee-growing parts of the Territory, the remaining scattered portions producing probably less than 5 per cent of the whole crop.

Kona and east Hawaii produce approximately 50,000 bags of clean coffee per year, more than 80 per cent coming from Kona. About 6 bags of coffee cherry, or 600 pounds, are required to yield one bag, or 100 pounds, of cleaned and dried coffee. This means that of the 30,000,000 pounds of coffee cherry produced, 5,000,000 pounds are marketable coffee. It requires 120 pounds of coffee in the parchment to make 100 pounds of clean coffee ready for market, the loss of 20 pounds representing the horn skin, or parchment, the silver skin, and an occasional bad bean. For every 500 pounds of marketable clean coffee there have been eliminated 100 pounds of this waste material. There are, therefore, approximately 1,000,000 pounds of this dried material produced annually.

The proportion of weight of pulp to the entire weight of cherry has not yet been carefully worked out at the coffee mills, since there was no special reason for determining it, and further because water is usually added in the pulping process. From two 10-pound samples of coffee cherry gathered from the station plantings on Mount Tantalus it was estimated that the pulp constituted approximately 47 per cent, including the water lost in the pulping process. The wet beans represented 53 per cent of the whole and the pulp contained 80 per cent water. The proportions of pulp and of moisture in the pulp would vary with different climatic conditions, and with the different varieties of coffee, but these figures are only approximate.

From the 30,000,000 pounds of cherry there would be 14,100,000 pounds of pulp. Of this, 20 per cent, or 2,820,000 pounds, represents the weight of dry matter.

To summarize, it may be said that at present the by-products from the coffee cherry in Hawaii are about as follows:

	Pounds.
Parchment and silver skin	1,000,000
Pulp:	
Containing 80 per cent moisture	14,100,000
Moisture free	2,820,000

This material, if desired, could be secured chiefly in the late summer and the autumn when the crop is being gathered and milled. It is difficult to estimate the weight of prunings that might be available for the purpose of caffein extraction. Many of the plantations or coffee farms do very little pruning; a few others prune quite systematically. At the present time there may be 2,000,000 pounds of prunings, but this amount would increase manyfold were the material to be sold at a price high enough to pay for the cost of the labor. While the advantages of judicious pruning are recognized in Hawaii, the prevailing precarious conditions of the coffee business has caused growers to hesitate to undertake the expense of pruning, particularly now that labor is so high and difficult to secure. Those widely scattered prunings now available are practically waste and they can be secured for little more than than the cost of gathering.

The dry products, silver skin and the parchment, generally used for fuel, are considered waste products at some of the mills. These could probably be available for the extraction of caffein if this operation proved profitable. The silver skin and parchment are centered at some of the half dozen mills in Hawaii.

The pulp is used in part as fuel, but the most of it is returned to the soil to act as fertilizer. Its value as fertilizer probably would be a criterion of the price required to secure the material for some other use. In November, 1911, an analysis of coffee pulp as a fertilizer was made by Mr. S. S. Peck, at that time chemist of the experiment station of the Hawaiian Sugar Planters' Association. Through the courtesy of Mr. P. S. Burgess, chemist of that station, a copy of the analysis made is submitted herewith.

Analysis of coffee pulp.

	Moisture free.	Original material.		Moisture free.	Original material.
	Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
Water	.....	62.00	Potash	3.91	1.49
Phosphoric acid	0.54	.21	Total ash	9.97	3.79
Nitrogen	2.18	.83			

In addition to the actual content of its fertilizing constituents, coffee pulp is thought to be quite valuable as an amendment to the soil. In a tropical country where humus is rapidly depleted from a soil that is kept constantly under cultivation it is important that the

value of the pulp as a substitute be considered. Coffee pulp is much more widely scattered than parchment and silver skin because many small growers do their own pulping with hand pulpers or by those operated by gasoline engines. A considerable portion of the pulping work is, however, centered at two or three mills.

VANILLA.

Some attention was given to the present status of vanilla cultivation in Kona, where two or three attempts were made to establish an industry. Capt. R. V. Woods is successfully producing vanilla beans and an extract of fine quality. In another part of Kona a large number of healthy vines were found climbing onto trees in a tropical jungle where an extensive vanilla plantation had been abandoned. Were a number of cuttings from these plants disseminated for trial among coffee growers and others they undoubtedly would make thrifty growth in some parts of the Territory even better adapted to the needs of vanilla than Kona. The plant requires humidity and heat, and Kona is inclined to be cool in most of the humid parts. The vicinity of Hilo or the Puna districts of the island of Maui probably would prove favorable spots for future tests.

PINEAPPLES.

The propagation and planting of seedling pineapples was furthered and several thousand of the young seedlings were placed in the commercial pineapple fields of different localities. A few of the first plantings made under these conditions are now beginning to fruit. Interest in the growing of pineapple seedlings developed to a remarkable degree and the work was entered into by the Hawaiian Pineapple Packers' Association on a scale exceeding the financial means of this station. It is gratifying to see this promising work being developed in such a vigorous manner.

THE ALGAROBA TREE AND RELATED SPECIES.

A number of species of Prosopis, introduced as seeds from several parts of the American tropics, were planted on the station grounds, where they are under close observation. Some of these are about to begin to fruit, and the character of their fruit and foliage will soon be apparent. Several thousand seedlings were grown from the seeds of selected trees in cooperation with plantings made by those who are interested in the algaroba-bean industry as a source of ground feed for stock. Some of these were distributed on the other islands of the group, and near Honolulu, where a large planting was made, plans for future observations are under way.

NEW OR RARE PLANTS.

Through the kindness of Mr. John Scott, of Hilo, the station was presented with a number of fruits from the only bearing tree in Hawaii of the ivory nut palm (*Cœlococcus carolinensis*). These nuts, which are illustrated in Plate V, figure 1, are the source of a material which is known as vegetable ivory, and which is frequently used in the manufacture of buttons and similar products. Although this tree will probably be of little, if any, economic importance to Hawaii, it is of considerable interest as an ornamental and as a specimen of an economic plant. Some of these seeds are sprouting in the station greenhouse despite the fact they are said to be difficult of germination.

The Mandarin vine (*Holmskioldia sanguinea*), which was collected by the horticulturist in Porto Rico in 1914, is proving to be a valuable acquisition to the ornamental plants of Hawaii. While it is naturally a climber, it can be grown without support. From a distance its handsome, brick-red colored bracts suggest the brick red variety of the bougainvillæa.

Among the other new or recently introduced plants are a superior variety of Chinese jujube (*Zizyphus jujuba*); Paraguay tea (*Ilex paraguayensis*); a timber bamboo (*Phyllostachys bambusoides*); several varieties of pineapple; several species of Cinchona, which furnish the cinchona or Peruvian bark, the source of quinine; several species of citrus relatives; snake gourd or Guada bean (*Trichosanthes anguina*); and several varieties of mulberry.

HORTICULTURAL EXTENSION WORK.

A large part of the time of the horticulturist is at present required in extension-work activities. During the past two years some of these were carried on in connection with the annual Territorial fairs, one of the main objects of which was to foster and further interest in local production so as to increase the food supply of the island. The exhibit of the horticultural division, which occupied one side of the station booth, showed some of the more recently introduced plants, the methods pursued in propagating pineapples from seed, a number of tropical fruits which were preserved in exhibition jars, the method pursued in growing strawberries in a barrel on small city lots, Macadamia nuts shelled and unshelled, and served as a confection after having been prepared by dipping in chocolate or in fondant; and sundry other features illustrating the work of the division.

During the few months preceding the fair, the attention of the horticulturist was directed chiefly to activities of the several committees on fruits, vegetables, field crops, and flowers. This year, in connection with the prize contest conducted by the Honolulu Star-Bulletin with the cooperation of the department of public instruction, he again acted as one of the judges of school and home gardens of the

children on the island of Oahu. It is gratifying to be able to record that since this work was begun there has been a marked improvement in the gardens both at the schools and at the homes. Some of the children walked miles in order that they might take advantage of the plats available for their gardens; in some cases, not only tools and manure were carried long distances, but daily trips were made so that the plats might receive watering and other cultural attention, and many young people carried the produce on their backs to a suitable marketing place.

The writer, while on a trip to the island of Hawaii, elsewhere referred to, made observations on the progress of the island's food production, and gave demonstration lessons in budding and grafting to some of the collaborators of the station and to others who would impart the knowledge. An increased interest in food production work was aroused among plantation owners, and laborers, homesteaders, and the planters of small holdings, and suitable opportunities presented themselves in many parts of the island for the further distribution of food crops, especially the selected varieties of sweet potatoes, cassava, edible canna, and papaya.

On the Parker ranch, at Waikii, splendid work in the production of about 3,500 acres of first-class corn was accomplished, and Mr. A. W. Carter, the manager, estimates the weight of corn produced equal to the entire importation of wheat flour in Hawaii during the last year.

It was noted that all along the Hamakua coast and in Kona plantings of upland taro were being made as rapidly as it was possible to secure this stock for propagation; this bespoke interest and enthusiasm in a material which had not only advanced in price, but was hard to secure.

One of the most interesting observations in Kona was that of the successful growing of squashes, pumpkins, watermelons, and even muskmelons. For the last 20 years it has been impossible to grow muskmelons or cantaloups in the Territory because of the devastations which resulted from attacks of the melon fly. The parasites introduced to control this insect have proved a success in this respect. Entomologists attribute the fact to prevailing excellent conditions which tend to aid its work. In almost every part of the district there is found a cucurbitaceous vine known as the wild cucumber (*Momordica charantia*), the fruit of which acts as a favorite host for the melon fly. Fortunately, it is a fruit into which the parasite can penetrate and find the larvæ of the fly. This wild plant functions as a trap into which the melon fly lays its eggs, which are destroyed in a later stage of their development.

The Kona orange is again coming into its own after having suffered from scale-insect and fruit-fly attacks. Citrus trees thrive very well

in Kona. In fact, it is doubtful whether any other part of this Territory gives greater promise for the successful cultivation of the finer varieties of oranges, grapefruits, lemons, and limes. It would be worth while to increase the planting of all of these kinds of citrus in Kona.

The station is confining the distribution of seeds and plants, as far as possible, to a few sorts which it has produced, or to those considered most important for general growth, and which can not be readily obtained elsewhere. Many thousands of seedlings of the station variety of tomato bred as a resistant to the melon fly, and an equally large number of papayas of the station variety were distributed. The practice of the station has been to disseminate seeds of these new varieties rather than the plants, except where only a few plants can be grown, as on small city lots.

The burden of extension-service work was further enhanced by a daily increasing number of telephone and letter inquiries for information covering a wide field of horticultural and related subjects.

REPORT OF THE CHEMICAL DIVISION.

By Maxwell O. Johnson and Kim A. Ching.

As food shortage conditions prevailed during the greater part of the fiscal year, the chief work of the chemical division consisted of studies of means and methods for the preservation and utilization of food. Experiments were made in drying and canning local fruits and vegetables. Investigations covering the manufacture of starch from a number of different local sources were made, and the manufacture of vinegars received much attention. Vinegar, which when tested surpassed the required local standard (4 per cent acetic acid), was successfully made from pineapple juice. A number of analyses were made of home-grown feeding stuffs and of soils, and an extensive fertilizer experiment with bananas was started. The investigations on the biochemical effect of manganese were continued.

DRYING HAWAIIAN FOOD PRODUCTS.

During the past fiscal year experimental work in drying was greatly facilitated by the completion of a large tower drier and the installation of a small vacuum drying system. The tower drier holds trays 3 feet wide by 4 feet long. A blower, driven by a small gasoline engine, forces air around steam coils and up through the trays in the tower. Regulation of temperature can be had by varying the number of steam coils used, and by altering the steam pressure. The velocity of the air can be controlled by changing the speed of the blower. Experiments were run on a semicommercial scale with this drier and

satisfactory results were obtained. In the following table is shown the percentage of dried fruit and vegetables obtained from the tower drying system:

Yield of dried fruit and vegetables produced in tower drier.

Materials.	Weight of original.	Weight of peeling.	Weight of peeled root or fruit.	Weight of dried product.	Dried material from original.	Dried material from peeled root or fruit.	Moisture loss.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Per cent.*	*Per cent.*	*Per cent.*
Sweet potato	200	39¾	160¼	53	27.0	33	67.0
String beans	10	.....	.....	1½	14.4	.....	85.6
Carrot	8¼	.....	.....	1¼	15.1	.....	84.9
Turnips	5¾	.....	.....	⅞	7.6	.....	92.4
Cabbage	8	.....	.....	⅞	11.2	.....	88.2
Cucumber	9⅛	.....	.....	7/16	4.8	.....	95.2
Pineapple	38	10	28	5⅛	13.4	18.3	81.7
Papaya	8⅛	1⅛	7	1 5/16	11.5	13.4	86.6
Mango	7½	*a* 4⅞	2⅝	1¾	23.3	66.6	33.4

a Peeling weight, 2⅛ pounds; seed weight, 2¾ pounds.

PRESERVING HAWAIIAN FOOD PRODUCTS.

A number of unsuccessful attempts were made to preserve the avocado fruit, as when heated, to sterilization temperature, the fruit developed a very bitter disagreeable flavor. The best method employed so far was that of cutting the peeled halves into small cubes, handling them meanwhile as aseptically as possible. After this the cubes were placed in a sterilized jar, which was filled with an ordinary commercial tomato cocktail sauce heated to the boiling point. Avocado preserved in this manner has kept in good condition for a year.

Papayas may be preserved in a manner similar to the avocado, or the two fruits can be combined.

Experiments were also made in the utilization of pineapple juice, which is a waste product of the canning industry. By mixing and boiling down equal parts of clarified pineapple juice and guava extract, a very good jelly, which was considered greatly superior to ordinary guava jelly, was obtained. Pectin precipitated from guava extract by alcohol and added to pineapple juice made a good jelly after being boiled down. Experiments were made in concentrating pineapple juice by freezing. This method, which gave good results, consisted in freezing the juice in an ice-cream freezer and separating the concentrated juice by centrifugal action.

MANUFACTURE OF STARCHES.

An attempt was made to manufacture starch from pineapple stumps. Extraction of the starch was made by grating the stumps, which contained many hard fibers. Because of a slowness in settle-

ment, due to the fineness of the starch grains, some trouble was experienced in separating them from darker woody particles. About 2.5 per cent of starch, based on the weight of the stump, was obtained.

Starches were also extracted from the root crops of taro, sweet potato, edible canna, Irish potato, cassava, and from Guam corn, rice, arrowroot, banana, and tree fern. Results of these experiments are being prepared for publication in bulletin form.

MANUFACTURE OF VINEGARS.

In a previous report of this station[9] a former chemist stated that experiments with pineapple juice were made for the manufacture of vinegar, but that it was found impossible to make a product which would comply with the legal standard requirement for acidity.

Experiments with pineapple vinegar were conducted during the past fiscal year. A pineapple juice, testing 11° Brix, was secured from one of the pineapple canneries. This was heated to boiling, poured into a carboy plugged with cotton, and, on the following morning, inoculated with common bread yeast. Very active fermentation took place, and by the third day the juice had settled. Samples taken on the fifth day showed an alcoholic content of 5 per cent. The product of fermentation was a cider-colored clear liquid which was poured off from the settlings. After some difficulty was experienced in obtaining active vinegar bacteria, a fairly active cider vinegar was secured and mixed with the fermented juice in parts of 1 to 4 and 1 to 8 of the juice. The mixtures were placed in glass vessels having cheesecloth covering. Two and a half months later a very active vinegar fermentation had taken place and a heavy layer of mother of vinegar had formed. The mixture of 1 part to 4 of juice contained 4.2 per cent of acetic acid, and was pronounced of fine quality by local experts. There should be no longer any difficulty in the manufacture on a commercial scale of vinegar from pineapple juice, especially now that active cultures of vinegar bacteria have been secured, and a quick process can be had by means of vinegar generators.

ANALYSES OF FEEDING STUFFS.

The following analyses have been made as the result of considerable interest manifested in the development of local sources of supply of feeding stuffs:

[9] Hawaii Sta. Rpt. 1913, p. 34.

Chemical analyses of some Hawaiian feeding stuffs.

Feeding stuff.	Water.	Ash.	Crude protein.	Carbohydrates.		Fat.
				Fiber.	Nitrogen-free extract.	
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Pigeon pea meal (stem, leaves, and pods)	11.9	2.96	9.21	38.73	34.53	2.67
Coconut meal	10.7	6.09	17.15	11.14	44.13	10.79
Fiber from pineapple stump after starch extraction	10.83	.91	3.5	15.12	68.98	.66
Mixed feed	13.31	8.11	8.57	12.58	54.64	2.79
Brazilian velvet-bean meal (stem, leaves, and pods)	10.20	6.48	6.21	12.69	62.91	1.51
Fiber from good pineapple plant after extraction	9.73	2.07	3.67	17.20	65.74	1.59
Sisal stump	76.7	1.29	.35	7.07	14.26	.33
Cane top meal	7.05	5.85	4.72	31.48	50.05	.85
Alfalfa meal	8.37	3.89	14.86	28.88	41.63	2.37
Mung bean (*Phaseolus radiatus*)	13.06	3.88	24.67	4.41	52.68	1.30

FERTILIZER EXPERIMENTS WITH BANANAS.

During the past three years fertilizer experiments with bananas were carried on; solutions containing fertilizing salts were used as sprays, and various mixtures of the more insoluble fertilizers were applied to the axils of the leaves. In March, 1919, a new planting of about 5 acres was made at Mokuleia, Oahu, and utilized as a large fertilizer experiment. Most of the fertilizer experiments were based on the triangle system which seems to be one of the best methods proposed for this purpose.

The first application of fertilizer was made in April, 1919, and it is planned to make this experiment continuous so that results will be secured on successive ratoon crops as well as on the first crop. Should a fertilizer producing good results be secured, it will be of great benefit to the grower, who profits principally from the shipment of large bunches of bananas, the smaller bunches being of little commercial value.

FERTILIZER EXPERIMENTS WITH PINEAPPLES.

Fertilizer experiment on pineapples, mentioned in last year's report,[10] made by applying various mixtures of the more insoluble fertilizers directly to the heart of the plants, is progressing and the plants are now producing fruit. Dried blood applied in this manner gave the best results, and a fine stand of fruit, superior to the check rows on either side, is developing. Fish scrap, which was applied in the same manner, produced very dark green healthy plants. Unfortunately, the last application was made at a time when some of the plants were budding and as a consequence the fruit was more or less distorted and injured. Steamed bone meal produced small but positive benefit.

[10] Hawaii Sta. Rpt. 1918, p. 24.

MANGANESE INVESTIGATIONS

In the report for 1918[11] a description was given of an experiment on manganese soil to which sulphur, at rates of 500 to 3,000 pounds per acre, a red very acid soil at rates of 1 to 6 tons per acre, and bagasse soaked in strong solution of iron sulphate at various rates, had been applied. None of these soil treatments were successful in supplying iron to the pineapple plants, and those on the treated plats became chlorotic at the same time as the checks. After spraying the whole plat with the iron sulphate solution,[12] however, the plants became green and healthy in a short time. It is a fact worth noting that applications of iron sulphate to the soil, at rates varying from 500 to 3,000 pounds to the acre, were unsuccessful in preventing chlorosis, yet the spraying treatment in which considerably less than 50 pounds of iron sulphate per acre was applied to the leaves, promptly cured the chlorosis. The application of the iron sulphate to the soil was effected by soaking bagasse with the iron sulphate, then applying the soaked bagasse and incorporating it in the soil.

REPORT OF THE AGRONOMY DIVISION.

By H. L. Chung.

The agronomy division accomplished good work during the fiscal year 1919, dealing primarily with the emergency food crops for man and animal. The work covered included breeding, fertilizer experiments, variety testing, and distribution of planting stocks of new improved varieties.

CORN.

During the past year two varieties of corn. the Guam and the Cuban Red, have been under test at the station in Honolulu. They represented the two strains selected from a number of varieties for ideal type and yield. The Guam variety produced at the rate of 52.5 bushels to the acre in 1919, an increase of 5 bushels over the crop of 1917–18, while the Cuban Red yielded at the rate of 30.4 bushels.

The Guam variety was characterized by prolificacy, two or three ears appearing on a single stalk. Both varieties, however, were wanting in the desirable length of the ears. This defect, in large measure, was responsible for their low yield. It is thought that constant and careful selection will eventually result in ears developed to the desired length.

While the Guam corn appears to be one of the most resistant varieties to conditions as far as the leaf hopper in Hawaii is concerned, its market possibilities are and will be limited as long as the cosmo-

[11] Hawaii Sta. Rpt. 1918, p. 24.

[12] Hawaii Sta. Press Bul. 51 (1916).

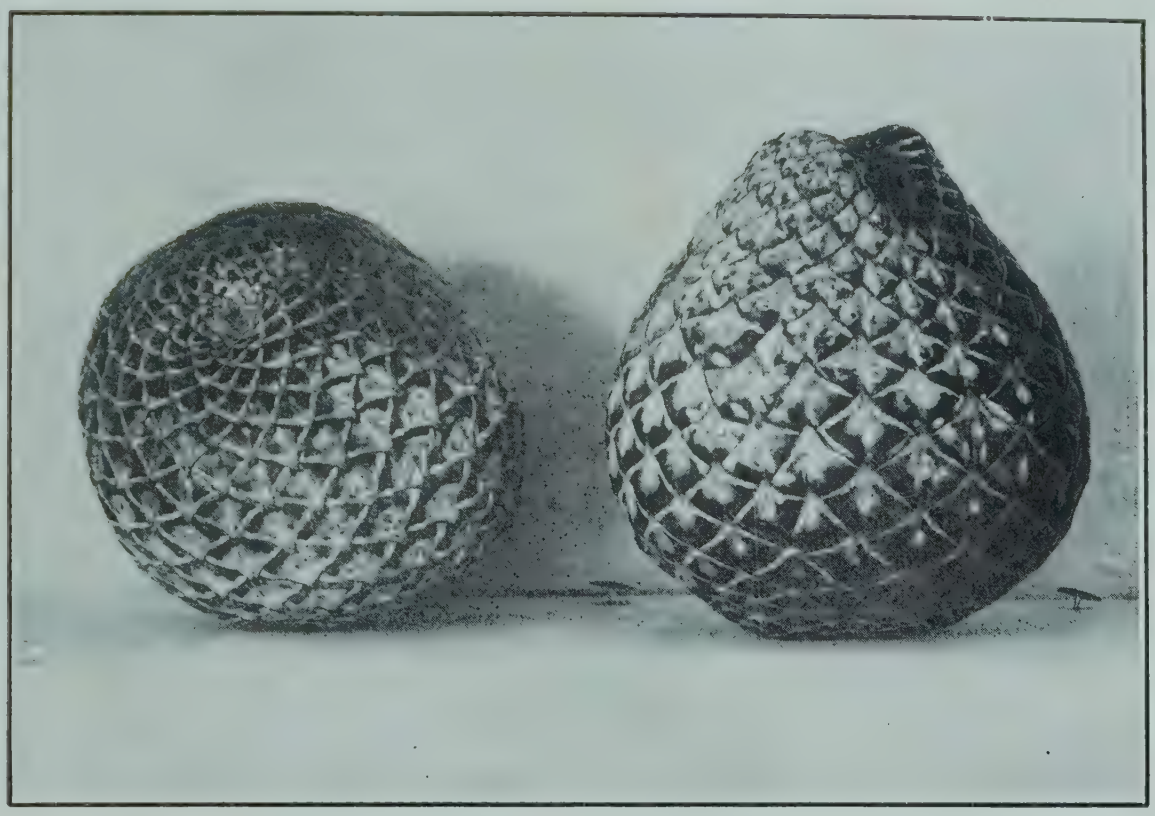

FIG. 1.—FRUIT OF IVORY NUT PALM (CŒLOCOCCUS CAROLINENSIS).

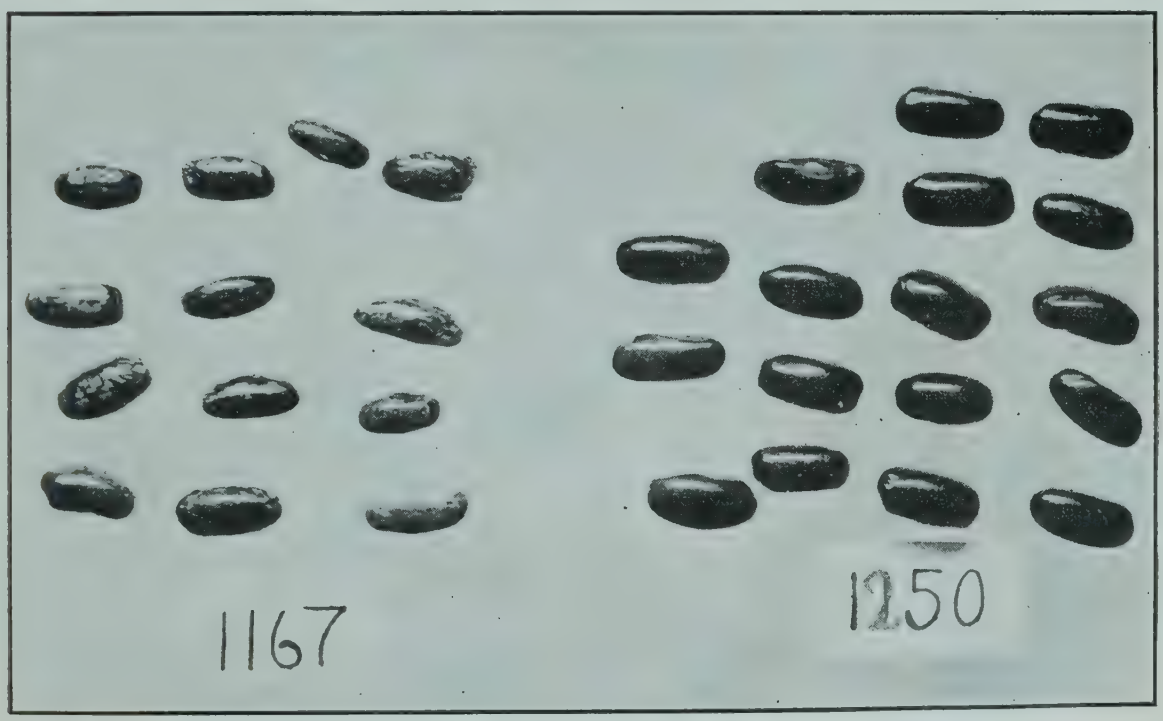

FIG. 2.—A BEAN MUTATION. ORIGINAL ON LEFT, MUTANT ON RIGHT. DARK BLUE GROUND COLOR SAME IN EACH. NO MOTTLING ON MUTANT.

FIG. 1.—A PROMISING SWEET POTATO HYBRID (C89A).

FIG. 2.—HEAVY PRODUCING STRAIN OF PIGEON PEA.

politan population demands a yellow corn. For this reason, the local markets rarely handle any white corn. Because of this peculiar condition the agronomy division is preparing to meet the demands of the future market by hybridizing the Guam corn with some yellow varieties in order to ultimately develop a yellow variety which will possess the desirable characteristics of the Guam corn.

CASSAVA.

A fertilizer experiment on a small scale was carried on in field N at the station. Results are not yet available as the plants are only in their tenth month of growth.

Varietal tests with cassava are also being conducted in the same field, the object being to introduce superior varieties. The tests consist of five varieties, imported from the Philippine Islands through the courtesy of P. J. Wester, horticulturist for the Philippine government, and four varieties from the mainland, selected personally by F. G. Krauss of this station.

The importance of the cassava as a root crop is exemplified by the number of its cuttings, which were distributed in lots of from one to two dozen to individuals. The value of the cassava as a carbohydrate feed for hogs is recognized, the hog raisers of Hawaii frequently requesting from one to nine thousand cuttings of the best varieties.

BEANS.

Since 1917 garden beans of different varieties have played an important rôle in the make-up of small backyard gardens and military company gardens. In fact, the bean was found so important that much time and care was devoted to developing heavy producing strains of the several varieties suggested by the emergency food crop program. Selected beans in lots of from 1 ounce to 1 pound are generally allotted to each applicant to whom the recommendation is made to allow one-half of the crop to go to seed.

Mutation in beans.—A mutation was observed among the Early Refugee variety, No. 1167, a strain harvested after its third generation of growth from selected seeds. The sport of a single plant was discovered among the 200 individual plants when undergoing further selection in the laboratory. Forty-seven of the sport beans were planted. In each generation, and for three successive generations, they reproduced beans identical with the original mutant in physical appearance. Both the parent and the mutant beans showed the same peculiar dark purplish ground work color not possessed by any other lot of beans under test. The dissimilar characteristics between the parent and the mutant (see Pl. V. fig. 2) are summarized as follows:

Dissimilar characteristics observed in beans of parent and mutant plants.

	Nature of growth of plant.	Color of fresh pod.	Color of matured bean.	Length of bean.	Width of bean.
				Inch.	*Inch.*
Parent	Bush	Olive green	Dark purplish blue with light orange mottling.	½	3/16
Mutant	do	Wax yellow	Dark purplish blue	17/32	9/32

Mr. E. J. Mooklar, formerly of this station, tested the edible quality of the sport bean and pronounced it very succulent and tender, when cooked, and one of the best edible-pod beans.

SWEET POTATO BREEDING EXPERIMENTS.

Preliminary work with sweet-potato breeding was begun in December, 1917. The object of this project was to create some new varieties possessing, among other desirable characteristics, early maturity as the predominant feature. While the parents used for this purpose had both good and bad qualities, the work was begun with the hope that by hybridizing certain individuals the desired characteristics could be obtained from some of their seedlings. However, the seedlings produced from the same seed pod revealed the fact that most of the parents used were multiple hybrids. In many cases where three seeds from the same seed pod were planted, three seedlings, each having a distinct leaf pattern, arose. The results expected from such seedlings may not, therefore, be in accordance with the actual realization. The present work gives every indication of promising results. Seedling C89A has proved to be a very prolific individual, having purple and white mottled flesh (Pl. VI, fig. 1). Seedling C111A as an edible is one of the finest varieties of sweet potatoes, being nonfibrous and very mealy.

MISCELLANEOUS CROPS.

Field turnips.—Plantings of the seeds of the round field turnip (*Brassica rapa*), the sample of which was received from Canton, China, were made 18 inches apart in 24-inch rows in field N. When harvested after a growing period covering 18 weeks, the crop gave a calculated yield of 43.5 tons per acre. Individual roots measured 12 inches in diameter and 9 inches in length.

Pigeon peas.—Work on pigeon peas was confined to the growing of seeds selected from high seed-yielding strains (Pl. VI, fig. 2) for general distribution among the poultry raisers. The peas serve as a substitute for corn and other grains commonly marketed as poultry feed.

Dry-land taro.—At the first Territorial fair in 1918 the taro exhibit demonstrated the several ways of successfully growing taro by adapt-

ing the plant to climatic and soil conditions of the different localities in Hawaii. The dry-land varieties attracted considerable attention among the homesteaders and landowners whose lands are non-irrigated. This station has received many requests from interested parties for dry-land taro for propagation purposes, but owing to the limited supply only a very small quantity was furnished to each applicant.

CASTNER FORAGE-CROP STATION.

On account of the unusual drought which prevailed at the forage-crop station at Castner progress with some of the introduced forage crops was retarded. In 1918–19 a rainfall of only 30.32 inches, compared with 58.56 inches of the previous fiscal year, was responsible for considerable retardation in the growth of all grasses. As a result some of these grasses died, while others have had a hard time to exist.

ROOT CROPS.

Cassava.—An extensive fertilizer experiment was instituted at Castner during the fiscal year 1918. The cassava was planted April 2, 1918, and will be harvested in September, 1919.

That the drought had a deteriorating effect on the plants is proved by the very poor growth of the cassava. The branches are undersized and the leaves are proportionately small.

Edible canna.—The edible canna was found to be desirable either as a soiling crop or a crop for starch production. Once the plant gets the proper start it will grow without need of further attention.

At Castner 8 plats with hills spaced at 3 by 6 feet were planted to this crop and after 14 months' growth the following data were secured:

Results of experiments with edible canna at Castner.

No. of plat.	No. of hills.	Plat yield.		Calculated acre yield.		No. of plat.	No. of hills.	Plat yield.		Calculated acre yield.	
		Tubers.	Tops.	Tubers.	Tops.			Tubers.	Tops.	Tubers.	Tops.
		Pounds.	*Pounds.*	*Tons.*	*Tons.*			*Pounds.*	*Pounds.*	*Tons.*	*Tons.*
1	4	68.75	40	20.79	12.1	5	4	63	46	19.05	13.89
2	4	73.75	47	22.35	14.21	6	8	104	76.75	15.73	11.6
3	4	68	40	20.57	12.1	7	4	74	40	22.38	12.1
4	4	62	43	18.75	13	8	4	77	47	23.29	14.2

Despite the dry weather the edible canna made a remarkable growth. In the company gardens the plant attained a height of 10 feet where irrigated.

Field beets and field carrots.—Where irrigation can be made available, these two root crops bid fair to become the succulent feed for horses and cattle of the Wahiawa district. The Giant White carrot

and Long Red mangel produced roots weighing 6 and 12 pounds, respectively, after a period of 10 months' growth without irrigation.

Potatoes.—The hot and dry weather made the planting of potatoes at Castner impracticable. When attempts were made to plant the Hamakua Hybrid variety under the unusual weather conditions, it was found that the cut potatoes were dried by the intense heat before they had a chance to sprout.

On May 23, 1919, seed potatoes, certified in New York to be blight resistant, were received by the pathological division of this station and turned over to the agronomy division for trial planting. Samples were distributed to the military company gardens for cooperative tests. At the time of this report (June 30, 1919), no sign of blight is to be observed on any of the plants.

LEGUMES.

Annual white sweet clover.—This clover (*Melilotus alba annua*) was sent to this station by Prof. H. D. Hughes, of the Iowa Agricultural Experiment Station, Ames, Iowa. A portion of the seeds was planted at the forage-crop station, where the plants spread well, made vigorous growth, and showed good seed-producing characteristics. This sweet clover will be planted on a larger scale at the station in Honolulu in order to determine its value as a feed for cattle and horses.

Alfalfa.—The attempt to grow alfalfa without irrigation at Castner was unsuccessful. It would be apparently impracticable and decidedly unprofitable for a farmer to try to grow alfalfa on a large scale without the aid of irrigation even in Wahiawa, the farming district immediately adjoining the reservation. The alfalfa at the substation is making very little growth on account of the extreme drought.

GRASSES.

The grass plat experiments at Castner were also handicapped by the extreme drought. Certain of the grasses are evidently drought resistant, since they remain green, yet their growth is stunted and their palatable qualities affected.

Several species of grasses which were adapted to Florida conditions were sent by Mr. J. B. Thompson, of the Florida Agricultural Experiment Station, Gainesville, Fla., for trial planting at this station. Unfortunately the seeds failed to germinate.

The Merker grass (*Pennisetum merkeri*), another grass received from Mr. Thompson, is not only growing very luxuriantly, but is stooling heavily. In physical appearance it resembles the Napier grass (*Pennisetum purpureum*). Data on the yield are not available at this time.

RAINFALL.

The following tabulation gives the comparative rainfall readings in inches for the past two years at the substation at Castner:

Rainfall at Castner substation for the fiscal years 1918 and 1919.

Month.	Year.		Month.	Year.	
	1918–9	1917–8		1918–9	1917–8
	Inches.	*Inches.*		*Inches.*	*Inches.*
July	1.9	1.3	February	0.85	5.8
August	3.9	.96	March	2.4	3.6
September	7.4	5.8	April	.19	9.8
October	1.1	3.6	May	1.1	1.9
November	5.8	3.4	June	1.8	5.8
December	2.9	9.3			
January	.98	7.3	Total	30.32	58.56

DISTRIBUTION OF SEEDS AND CUTTINGS.

During the fiscal year the agronomy division distributed seeds and cuttings to the emergency war gardeners, dairymen, and to ranchers. For the 12 months ending June 30, 1919, seeds and cuttings were distributed to 425 applicants in amounts as follows:

Seeds and cuttings distributed during year ending June 30, 1919.

Crop.	Seeds.	Cuttings.	Crop.	Seeds.	Cuttings.
	Pounds.	*Number.*		*Pounds.*	*Number.*
Alfalfa	32	.....	Sorghum	53	.....
Beans	107	.....	Cassava	.....	34,529
Corn	480	.....	Uba cane	.....	3,324
Grass seed and cuttings	1,056	.....	Edible canna	.....	5,058
Pigeon peas	72	.....	Napier grass	.....	1,412
Dry-land rice	25	.....	Sweet potatoes	.....	12,771

REPORT OF THE DIVISION OF PLANT PATHOLOGY.

By C. W. Carpenter.

The division of plant pathology during the fiscal year 1919 continued the program of work set forth in the 1918 report. The Territorial county agents and other extension agencies cooperated with the division, and the pathologist, thus greatly relieved from the burden of extension and demonstration work on insect and disease control, was enabled to devote considerable time to investigation and experimentation activities. With the close of the war it was again found practicable to give attention to important research problems in which immediate practical results were less certain. The manuscript of a bulletin entitled "Potato Diseases in Hawaii and Their Control"[13] was submitted early in the fiscal year for publication.

[13] Hawaii Sta. Bul. 45 (1920).

TARO ROT.

A preliminary study of the disease reveals the fact that there are several forms of taro rot present in Hawaii. The grayish to brownish rot of the taro corm (the edible underground portion variously called root, tuber, bulb, etc.) is by far the most common and destructive type in the field. The appearance of the affected taro varies considerably, sometimes being gray, soft, and mushy like poi, and at other times more dry and firm and grayish in color, or having merely a brownish discoloration of the tissues adjacent to the large root fibers which traverse the corm. Pathological culture studies of taro rot as it exists in the corm while still in the soil has resulted in the isolation of a predominant organism which resembles *Pythium debaryanum*. Since this latter organism is generally considered responsible for a number of other vegetable rot troubles in moist situations and under favoring conditions,[14] is a parasite of no mean capabilities, there is every indication that this species or a near relative is the cause of the common form of taro rot. It has been previously noted[15] that this organism was found associated with a root rot of rice in Hawaii. A preliminary inoculation experiment with the taro organism resulted in rot of the inoculated taro, while in no case did the uninoculated but otherwise similarly treated taro develop rot (Pl. VII, fig. 1). The taro, kept in moist chambers, sprouted vigorously during the time of rot development, a fact which would indicate continued vitality. Furthermore, that the development of the organism is accompanied by the formation of an enzym is evidenced by changes of the tissues several centimeters distant from the point of inoculation and beyond a point where the organism can be recovered. In the only experiment of this kind attention was directed to these deep and distantly affected tissues and an attempt made to isolate the uncontaminated parasite resulted in failure to obtain the organism.

The organism *Sclerotium rolfsii* was found associated with a rot which occurred in taro several days after it was pulled. Further investigation on the causes of taro rot will be carried on at the first favorable opportunity.

A circular letter on taro rot, furnishing available information to taro growers, was prepared by the pathologist.

Taro rot investigations on Molokai.—A survey of the valley of Halawa, island of Molokai, showed the taro growing there to be in a precarious condition, owing to the presence of a taro rot disease. The rot was of the type previously mentioned as associated with the organism *Pythium debaryanum*. It was thought that conditions would be improved by letting the taro lands rest awhile, or by the

[14] Hawkins, L. A., U. S. Dept. Agr., Jour. Agr. Research, 6 (1916), No. 17, pp. 627–639.
[15] Hawaii Sta. Rpt. 1918, p. 43.

practice of crop rotation. However, the suggestions of resting the patches, rotating with rice, or even plowing and harrowing after drying them out, met with little enthusiasm among the planters who make their land serve as the chief means of livelihood. As a result of continuous cultivation covering a long period, the soils have become very acid and otherwise unfavorable to the crop, but it is believed that this condition can be best corrected by plowing up, aerating, and resting the lands, or by planting them to other crops. Since there was no inclination to practice either method, applications of lime were recommended as a practicable way to ameliorate the existing conditions. A small demonstration experiment, carried on in cooperation with the trustees of the Bernice P. Bishop estate, was started on land of that estate in Halawa, in which tests with applications of lime, coral sand, and fertilizer were made. The selected land was a taro patch which, for several years, had grown very little marketable taro, most of which was more or less decayed when pulled up.

Mr. C. C. Conradt, of Pukoo, Molokai, consented to represent the experiment station in looking after the experiments in Halawa, in addition to acting as collaborator for this station on Molokai, where there is no regular county agent. Data on the results of the experiments are not yet available.

SPRAYING TO CONTROL THE BANANA FRECKLE DISEASE (PHOMA MUSÆ).

The banana freckle disease, described in the 1917 and 1918 reports of this division,[16] continued to do serious damage to the banana industry. As previously noted, this disease affects almost exclusively the Chinese or dwarf banana (*Musa cavendishii*). The disease spots the leaves and fruit; the former prematurely dry and fall, resulting in a general weakening of the plant; the latter appear blackened and disfigured, and unevenly ripen in small bunches.

The larger plantings at Mokuleia, where the bulk of the best fruit is grown, were so threatened by the disease that drastic methods were undertaken in a 100-acre plantation in an effort to check its progress. The pathologist is deeply indebted to Mr. A. J. Campbell, who not only made this cooperative project possible, but maintained throughout the work a keen personal interest and submitted valuable suggestions thereon. The campaign consisted of pruning the trees and burning the affected leaves, removing the upper portion of the stump when a bunch was cut to lessen the infection of the suckers, pulling out the worst affected and otherwise undesirable plants from about 25 acres, and planting cane therein. The more desirable younger fields were retained and sprayed with a fungicide. In the

[16] Hawaii Sta. Rpts. 1917, pp. 40, 41; 1918, pp. 36–39.

spraying work, attention was directed particularly to the upper surfaces of the leaves.

Preliminary experiments showed that Bordeaux mixture would not spread well on the waxy leaves, nor would the lime-sulphur spray. The addition of resin sal soda sticker to Bordeaux mixture, however, proved very satisfactory in overcoming the difficulty. The formula for Bordeaux applied generally in the work is that known as the 4:4:50 formula, though the 4:3:50 and the 5:5:50 formulas were applied to certain plats by way of experiment. The resin sal soda spreader sticker is prepared by boiling 1 pound of resin and one-half pound sal soda in 2 quarts of water until the proper degree of combination is effected. Subsequent experimentation with this formula and others showed that a more workable mixture resulted if the combination was as follows: 4 pounds resin, $2\frac{1}{2}$ pounds sal soda, and 2 gallons of water. Two quarts of the sticker was used with each 50 gallons of Bordeaux.

The Bordeaux mixture was applied with a 100-gallon capacity sprayer, equipped with two lines of spray hose 200 feet long, in 50-foot sections, so that desirable combinations could be readily used, depending on the distance of the plants from the sprayer. (See Pl. VII, fig. 2.) Eight-foot extension rods and small-capacity side-outlet cyclone nozzles were found practicable. Since a relatively long time must be spent on each plant in order to reach the leaves at the proper angle, the small-capacity nozzles were found to give more satisfaction than the larger ones. Temporary roads were constructed wherever needed through the plantation, and portable bridges were made for crossing irrigation ditches, etc.

It was found to be impracticable to thoroughly prune out all infections with a crop like bananas, since plants of various ages were affected, the young suckers becoming infected from the old plants, etc. Too extensive cutting of leaves of plants was found harmful to the fruit, and when attempted on rather young plants, the pseudo-stem later developed such a constriction at the top that the bunch could not issue normally; assisting the bunch to emerge did not result in any material improvement. A similar effect resulted from the pruning brought about by the premature falling of the leaves. It was found, however, that a few leaves could safely be removed, though it was rather difficult and almost impossible to teach the Chinese laborers the discrimination necessary.

As a result of eight months' prosecution of the pruning and spraying campaign on this plantation, there is every indication that the method will be a successful one. The plants throughout are looking very much better than when the campaign started. Conclusions either as to the effectiveness or practicability of the method can not be determined definitely at this time.

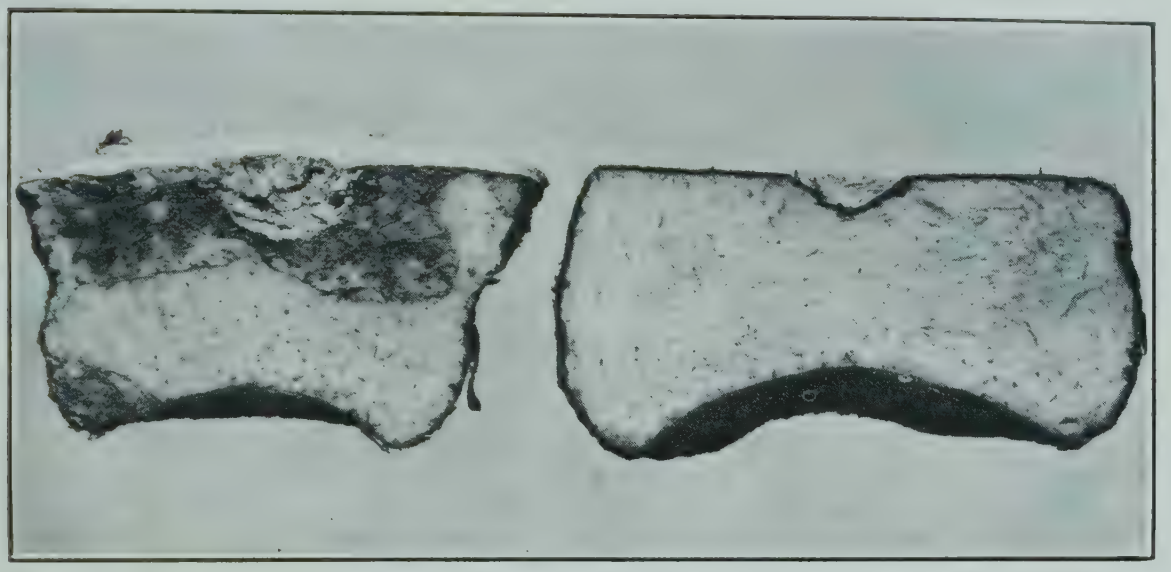

FIG. 1.—TARO ROT DISEASE DUE TO FUNGUS OF PYTHIUM DEBARYANUM TYPE. INOCULATED ON LEFT; CHECK ON RIGHT.

FIG. 2.—SPRAYING BANANAS FOR CONTROL OF FRECKLE DISEASE.

FIG. 1.—CONTROL OF MITE DISEASE OF PEPPERS. SPRAYED WITH LIME SULPHUR ON LEFT; NOT SPRAYED ON RIGHT.

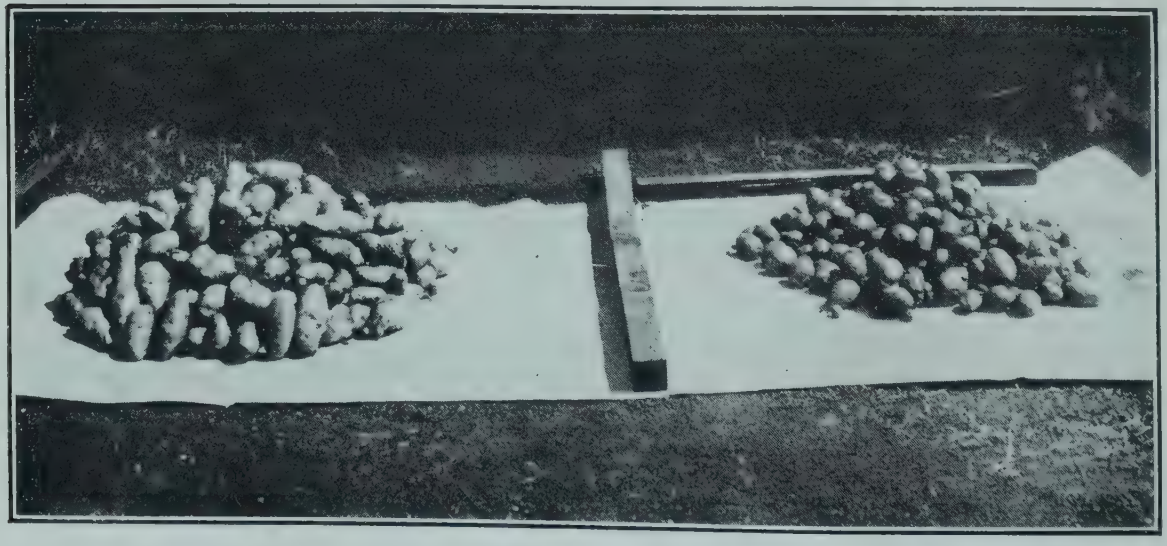

FIG. 2.—CONTROL OF MITE DISEASE OF POTATOES. SPRAYED WITH LIME SULPHUR ON LEFT; NOT SPRAYED ON RIGHT.

Recommendations to prevent the spread of this disease to other banana growing countries were made to the Territorial representative and inspector of the Federal Horticultural Board, and are being well carried out. Since the disease was observed on no island other than Oahu, suggestions were also made to the Territorial inspector to put into force certain restrictions regarding the transfer of banana suckers from Oahu to the other islands.

A MITE DISEASE AFFECTING SWEET PEPPERS.

A peculiar disease condition was noted on sweet peppers growing in dry and hot situations, and is characterized by the curling and stunting of the young leaves and buds. Though little attention has been focused on the disease, examination shows the symptoms to be practically the same as those previously noted[17] associated with mite infestation in the potato and tomato. Numerous mites are present, and the disease and its cause seem to be the same as that known as the potato mite disease. A small experiment carried on with diseased sweet peppers showed that applications of sulphur or lime-sulphur spray controlled the disease affecting them as well as that affecting potatoes. (See Pl. VIII, figs. 1 and 2.)

NEW ROOT-ROT PROJECT.

During the fiscal year the pathologist observed the presence of several very malignant diseases which call for immediate attention. As yet, however, their origin is more or less obscure, and while they have many conflicting symptoms and characters it is quite possible that some may prove quite identical in nature. Certain observations and work made to serve as a basis for a plausible working hypothesis were carried along the lines offering the most promise. This investigation, which is called the root-rot project, will include some studies on the microorganisms of Hawaiian soils.

MISCELLANEOUS NOTES ON PLANT DISEASES.

Among the microorganisms observed during the year and not noted in previous pathological reports are:

Sphærostilbe coccophila.—An entomogenous fungus, apparently parasitic on scale insects which infest the grapevines at Wahiawa, Oahu.

Sclerotium rolfsii.—A stem disease of peanut and affecting taro as storage rot.

Phytophthora calocasiæ.—Found in Oahu, Molokai, and Hawaii on taro leaves.

Cercospora bolleana.—Known as the fig leaf spot, and observed in Oahu.

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[17] Phytopathology, 8 (1918), No. 6, pp. 286, 287.

Sphærotheca pannosa.—Rose mildew, found in Oahu.

Nematodes.—These organisms were found at Pearl City and Mokuleia, Oahu, associated with root rot accompanying the banana center leaf necrosis disease and chlorosis, noted in the 1917 report of this division[18]. In Oahu nematodes were also found associated with the root and crown rot of hibiscus.

REPORT OF THE POULTRY DIVISION.

By L. M. Ross.

During the past several years the major part of the poultry work of the station was conducted at the Glenwood substation, where, under Hawaiian conditions, single-combed White Leghorns were bred specially for egg production. During the past year, however, some attention was given to poultry investigations at the central station at Honolulu. This particular work was carried out with the following objects in view: (1) To ascertain the best system of feeding poultry in the Hawaiian Islands in order to obtain the highest practicable standards of egg production; (2) the development of methods for the most successful brooding and rearing of young poultry; (3) the development of the most effective methods for combating poultry diseases prevalent in Hawaii; and (4) the general encouragement and development of the poultry industry in Hawaii.

SOREHEAD OR CHICKEN POX.

The susceptibility of young chicks to the inroads of sorehead constituted in times past probably the most serious drawback to the successful production of chickens under Hawaiian conditions. Officials of the Territorial board of agriculture and forestry have to a considerable extent overcome this disease by their gratuitous distribution of the proper vaccine. It was found that prompt isolation of suspects, the careful attention to sanitary conditions, and one or two treatments with some suitable antiseptic to the heads of the quarantined birds resulted in reducing the damage from sorehead to negligible percentages. It is thought that unsanitary conditions are highly responsible for the development of conditions which are favorable for the spread of sorehead in poultry flocks. Foul and dirty quarters are probably the most important predisposing factors. In Hawaii certain poultry raisers pay special attention to the provision of sanitary quarters and yards for their flocks; and their young and adult stock have, as a consequence, been free from sorehead. It has been deemed advisable to procure from a breeder foundation stock which has not been subject to sorehead infection, so that this

[17] Hawaii Sta. Rpt. 1917, pp. 36–42.

stock may not be a carrier of the disease. Strict sanitation should be practiced in such small matters as drinking vessels, roosting quarters, nest boxes, etc., and the poultry should be frequently transferred to fresh runs; the used runs should be plowed, dug, or planted to a crop in order to clean the ground. Where sorehead reached an advanced stage, calcium sulphid was found helpful. One tablespoonful of the powder mixed into a moist mash for each 25 hens should be fed daily until cure is effected.

POULTRY CANKER.

This disease is a very common one in Hawaii. In the course of a preliminary experiment, it was found that the following procedure ordinarily gives relief unless the disease has reached a far advanced stage. The ulcer, and portions of the flesh surrounding it—both inside and outside the mouth—must be painted with tincture of iodin immediately after the canker has been firmly compressed from the outside of the mouth; this compression will greatly eliminate the suppurated matter which is then ejected through the nostrils. Arrangements should be made to have handy a small pan, or other vessel from 3 to 4 inches deep, filled with kerosene oil. Into this kerosene the beak and nostrils of the chickens should be dipped, the head being held there for a few seconds. This operation should be repeated at least three or four times, after which a 1-grain capsule of quinine should be administered to each fowl. If this method of procedure be followed three or four days in succession, the canker will disappear and the chickens will be cured.

COMMERCIAL ASPECTS OF THE POULTRY INDUSTRY.

At the present time the poultry industry in Hawaii is relatively in its infancy, nor is it felt that much increase in the production can be expected until the poultry possibilities are thoroughly demonstrated on a practical scale, and the various drawbacks which now beset the average poultry raiser are overcome. Available statistics show that during the year 1917 some 497,261 dozen eggs, valued at $186,691, were imported into Hawaii from California; during the same year 77,090 dozen, valued at $15,132, were imported from foreign countries, chiefly from China. These figures clearly show that Hawaii holds great possibilities for the disposition of the product of increased poultry flocks in the islands.

REPORT OF THE EXTENSION DIVISION.

By F. G. Krauss.

Hawaii produced more food and feed stuffs during that period in which the United States was at war than during any equal period in her history. The agricultural extension division rendered every assistance to the work of stimulating and increasing this production. Throughout the war period close and active cooperation was maintained with the Federal and Territorial Food Administrations. The station's available agricultural data and the demonstrations conducted by it were always at the disposal of the Territorial county agents. Cooperative contacts were maintained with the Territorial agencies at all essential points, a fact which it is thought proved an effective factor in contributing to the excellent results achieved by the islands throughout the war period.

During the months of December and January a trip was made to the mainland of the United States, the journey covering ground as widely separated as California to Massachusetts and Florida. The major object of the trip was to obtain data regarding the production and utilization of cassava, but it was also found possible to get in close touch with the extension activities under way in several of the representative States, and in the United States Department of Agriculture at Washington, D. C. Collections were made of the data descriptive of the most successful methods along extension lines with the idea of adapting them to the peculiar conditions present in the Hawaiian Islands.

EXTENSION SERVICE WORK.

It is felt that a real service was rendered by the division in acting as middleman between the producer of food crops and those sources of information which gave any promise of being helpful to the producer. During the last 15 years cumulative and rather valuable agricultural information was gleaned from the various agricultural institutions and activities of the islands by the superintendent of the extension division. This information was placed at the service of interested parties at the experiment station library, the extension service library, and elsewhere.

In a number of instances plans were prepared for planting and for crop rotation, and working drawings were made for the construction of locally made farm implements, and even for farm buildings and for silos.

The attempt was made to maintain at all times a supply of seed, cuttings, and tubers, etc., of all the improved varieties of crops the increased utilization of which was recommended by the extension division to the island farmers. During the year improved planting

stock sufficient for over 1,000 acres was distributed. A large portion of the 40 acres under cultivation was devoted to the production of improved strains of seeds and planting material. Germination and purity tests of seeds were made for those requesting them.

The extension division was also instrumental in arranging for the distribution of approximately 100 young registered Berkshire pigs; this distribution was made at prices which not only enabled the farmer of limited means to purchase the pigs, but also enabled him to secure a foundation stock of superior breeding.

Extended trips through the principal islands were made during the year. By this means close contact was maintained with the more important diversified agricultural projects. Lectures on timely agricultural topics, and demonstrations of spraying, budding and grafting, home curing of pork, and caponizing, were held whenever an opportunity presented itself. Numerous timely articles were prepared for the local press. These articles have always met with a generous and prompt response from the public, and seem a most effective way of reaching the public at large. A neighborhood reading service was in active operation throughout the year. The various agricultural journals received by the extension division were pooled with those subscribed to by others and the entire collection was placed where it could benefit all. Extra copies of agricultural bulletins, etc., which were received by the extension division, were likewise passed along to those interested.

COOPERATIVE EXTENSION ACTIVITIES.

Cooperative relationships were maintained with the other divisions of the Hawaii Experiment Station as well as with the various Territorial and private agricultural institutions. Extensive feeding tests were carried on in cooperation with one of the larger agricultural companies, and, in a number of places, cooperative experiments and demonstrations dealing with special crops or improved agricultural practices were inaugurated. The various local agencies responsible for the school-garden contests, home-garden work, etc., continued to receive the active support of the extension division, as did also the Maui pig club. The superintendent of extension served as one of the judges for the school and home garden contests, and as chairman of the pig-club committee. Likewise, he cooperated actively as a member of the committee of Maui County for the second Territorial fair in Honolulu, and was appointed chairman of the agricultural committee for the Maui County Fair to be held in the autumn of 1919.

The work done in connection with the collaborators constitutes an important phase of the cooperative activities of the division. The collaborator, who represents the division among the farmers of the

particular neighborhood in which he is located, ordinarily owns, or, at least manages, the farm on which he works, while the demonstrations conducted by him are usually incidental to his major agricultural operations. During a whole or a part of the year there were four collaborators on the island of Hawaii, two on Kaui, two on Maui, and one on Oahu.

In cooperation with the Territory of Hawaii, the extension division is operating a demonstration farm unit in the newly opened homestead tract on the slopes of Haleakala. The object of this farm is to demonstrate, in the shortest possible time, just what can be profitably produced under the somewhat peculiar conditions of soil, rainfall, elevation, and exposure to winds. The homesteaders rendered very valuable assistance in breaking up the land, while the adjoining ranch generously assisted in the matter of fence construction. The Territorial legislature appropriated money for a small set of buildings, the money to come from the loan fund when there shall be a sufficient balance in said fund to make the outlay practicable.

EXTENSION ACTIVITIES AT THE TERRITORIAL FAIR.

The second Territorial fair at Honolulu offered unusual opportunities for exhibits of the most promising agricultural developments which resulted as an outcome of the intense wartime agricultural activities. The division was largely instrumental in stimulating active and enthusiastic interest among the numerous exhibitors and it entered about 75 individual exhibits, which showed a wide range of products raised on the Haiku demonstration and experiment farm.

One of the principal features of the exhibit of the extension division was its collection of various home-grown feeds suitable for grinding and mixing. This feed was displayed not only to serve as well-balanced rations for every class of live stock, but each feed, in the mixtures designed, was also properly proportioned to suit the needs of the different animals. (See Pl. IX.) It was shown that for various classes of live stock it is practicable to produce and mix home-grown feeds which not only furnish a palatable balanced ration, but which also can be produced at approximately half the cost of equivalent imported feeds.

ENLARGEMENT OF EXTENSION ACTIVITIES ON THE ISLAND OF HAWAII.

Although four collaborators were maintained on the island of Hawaii in connection with the work of the Glenwood substation, it is realized that even a larger working force is required to cover the agricultural work of the largest island in the group. This need was manifested especially when the Territorial legislature withheld its

financial support from the county agent system which developed during the war. On April 1, 1919, R. A. Goff, who has for some years been in charge of the substation at Glenwood, was appointed extension agent for the island of Hawaii. He had previously acted in this capacity in cooperation with the Territorial food commission for the region adjacent to Glenwood, as well as collaborating in the extension work of the station.

J. E. Gamalielson, one of the collaborators on Hawaii, is an active poultry raiser and serves as secretary of the Glenwood Creamery Co., a cooperative organization of farmers who market their butter through this agency after supplying local demands. A summary of the creamery business for the last year by months is given below:

Summary of business of the Glenwood Creamery Co. for the year ended May 31, 1919. [a]

Month.	Amount of butter marketed.	Average price per pound.	Total returns.	Cost of marketing.	Month.	Amount of butter marketed.	Average price per pound.	Total returns.	Cost of marketing.
1918	*Pounds.*	*Cents.*			1919.	*Pounds.*	*Cents.*		
June	340	57	$193.68	$10.24	January	358	70	$245.28	$14.32
July	429	54.4	237.65	13.88	February	322	63.04	203.02	12.24
August	402	56	224.94	14.24	March	554	61.37	334.47	15.36
September	420	57	239.26	14.16	April	427	65	277.44	13.44
October	353	57	202.00	13.48	May	435	67	291.45	14.28
November	185	57.8	106.92	7.24					
December	210	70.73	154.89	8.56		4,445	61	2,720.00	[b] 151.44

[a] A summary for the preceding five years was given in Hawaii Sta. Rpt. 1918, p. 28.
[b] About 5½ per cent.

On the farm of Mr. Gamalielson, at Kaumana, Hilo, Hawaii, a flock of about 300 laying hens is maintained not only as a part of the regular business, but also as a demonstration of the possibility of a regular supply of eggs. The production of eggs, by months, is given below:

Egg production for the year ended May 31, 1919.

Month.	Number of eggs produced.	Month.	Number of eggs produced.
1918.		1919.	
June	2,496	January	4,404
July	2,754	February	4,389
August	3,536	March	5,182
September	4,491	April	4,401
October	4,440	May	4,129
November	3,280		
December	3,241	Total	46,743

From the above table it will be seen that there was an average production of 155.8 eggs per hen. The falling off in number of eggs produced in November and December was due to culling the flock.

NEEDS OF THE EXTENSION DIVISION.

Although the division has grown and flourished since its inauguration in 1914, it has many needs. A very apparent need is that of a well-trained marketing agent who not only would be able to attend to the various features of cooperative marketing organizations, but who would also stimulate active interest in farmers' organizations as a whole, as well as devote considerable time and attention to the further development of club work.

The islands also need the development of the farm bureau, which demonstrated its effectiveness throughout the mainland portion of the United States. A properly constituted farm bureau should be organized in every agricultural community throughout the islands, and should correspond in many ways to the chambers of commerce of up-to-date cities. Such an organization would greatly facilitate the work of the county agent, since it would bring him the counsel and advice of the more progressive farmers on the most pressing agricultural problems and their solution.

For the ultimate good of the islands, steps should be taken to increase such various organized projects as boys' and girls' pig clubs, potato clubs, corn clubs, etc. This class of work has heretofore been confined almost exclusively to school-garden work, and as a result of having received a great deal of attention from a number of different agencies throughout the islands, has been an unqualified success. It is felt, however, that the work should be made to embrace more than the production of vegetables; in fact, it should include the systematic raising of farm crops and animals as well. A promising boys' and girls' pig club was recently organized on the island of Maui.

Throughout the islands the ready responses to the home economics demonstrations occasionally made possible by various local agencies clearly proves the desirability of and the need for additional attention to this line of extension work. An efficient home demonstration agent visiting the more or less isolated homes of the island would impart a great deal of up-to-date information and, as an outside influence, serve to increase the happiness and efficiency characteristic of the average individual American home. Each county should have a county agent or full-time representative of the extension division.

HAIKU DEMONSTRATION AND EXPERIMENT FARM.

The Haiku demonstration and experiment farm was originally planned as a demonstration farm. However, a number of local problems developed which could be solved only by actual field and plat experiments. As a result, the experimental features of the work have developed in conjunction with those of the demonstration

activities until the two have acquired equal rank on the farm which serves as the base of operations for the extension division. Every theory of practice is first tried out on this farm before it is definitely recommended to the Hawaiian farmer. The practical nature of the demonstrations under way is evidenced by the increase in the number of visitors to the farm. Not only residents of the island of Maui, but also many people from all over the Territory were numbered among its interested visitors.

The experimental work consists in comparative variety tests of new and improved forage and food crops in order to determine their adaptability and possible advantages under local conditions. Cultivation and fertilizer experiments are designed to give definite information as to the best method to be followed for producing those crops which are found to be best adapted.

Another phase of the work is the growing of seed of these crops in order that the improved strains may be quickly disseminated throughout the island. The crops involved in the above work are as follows:

Crops grown at the Haiku demonstration and experiment farm.

Crops.	Number of varieties.	Crops.	Number of varieties.
Cowpeas	16	Grain sorghums	5
Culinary beans	4	Field corn	20
Pigeon peas	4	Popcorn	2
Peanuts	2	Sweet corn	2
Soy beans	12	Cassava	4
Velvet beans	2	Sweet potatoes	2
Alfalfa	10	Irish potatoes	8
Pasture grasses	2	Dry-land taro	20
Forage sugar cane	2	Japanese yam	2
Nonsaccharine sorghums	5	Edible canna	1

In addition to the above-mentioned work with crops, a number of experiments are under way to determine their utilization. The relative merits of the various crops under test are ascertained by feeding them to poultry, swine, dairy cows, and work animals belonging to the station. In addition to these experiments, milling and mixing tests of the various cured products of the farm are made with a view to establishing commercially practicable mixtures of Hawaiian-grown feeds as a substitute for imported feeds.

The hay crops are usually cured on portable curing trucks. The milling of cured hay and grains, including corn, Uba cane, sorghum, cowpeas, velvet beans, pigeon peas, peanuts, cassava, etc., and the mixing of the same to form balanced rations, constitutes one of the most practicable phases of the work and already has resulted in the local establishment of a large commercial milling plant for the manufacture of mixed feeds.

Variety tests, fertilizer experiments, and breeding work with corn.—The work with corn which was inaugurated in 1915, shortly after the establishment of the demonstration and experiment farm at Haiku, continued to broaden in its scope. In the breeding work another variety or strain of corn was developed to supplement the New Era 100-Day Yellow Dent. The new variety, which contains the same blood lines as the older type, possesses them in different proportions and requires a growing season of 20 days longer. This is a favorable feature for localities having ample rainfall.

When the writer was in Washington, D. C., during the past year, an experiment was arranged in cooperation with the office of Corn Investigations of the Bureau of Plant Industry, United States Department of Agriculture, to compare, by testing, a number of varieties of corn at different elevations with those already under test. The following mainland varieties are under test in direct comparison with the New Era 100-Day Yellow Dent and the local Kula type of corn: Mill Pond Prolific, S. P. I. No. 45903, U. S. Selection 119, Taxpan, No. 133, and Johnson's Prolific. These were planted at an elevation of about 500 feet at the Haiku demonstration and experiment farm, March 21–23, 1919. The corn, carried as No. 133, harvested June 25, was the only one having ears which matured during the fiscal year just closed.

The yield of No. 133, from a plat one-third acre in size, was at the rate of 40 bushels per acre, despite the fact that it was planted rather late in an unduly dry season. A second planting was made at the Haleakala demonstration farm at an elevation of about 2,000 feet, and a third planting was made at Waiakoa (Kula district) at an altitude of about 3,000 feet. These plantings are not yet sufficiently mature to justify any definite comparison.

In addition to the above-mentioned cooperative experiment, variety tests with the following varieties are being continued: Blount's Prolific, Casey's Purebred Old Virginia Shoe Peg, Virginia White Dent, Cocke's Prolific, Boone County White, Silver King, Improved Paymaster, Improved Southern White Snow Flake, Eureka, Bigg's Seven Eared, Hickory King, Wood's Gold Standard, Improved Golden Dent, Reid's Yellow Dent, Improved Leaming, Virginia Yellow Dent, Victory Yellow Dent, Virginia Ensilage, Pamunkey Ensilage, and Improved Yellow Creole. The writer selected the last-named variety in Louisiana during the winter of 1918–19.

The fertilizer tests have proved that it is absolutely essential to apply phosphate fertilizers in order to obtain a profitable yield of corn. The most economical results were obtained from those plats where a mixture consisting of equal parts of reverted and superphosphate had been applied at the rate of 500 pounds per acre.

Pigeon peas.—Probably the most important demonstration of the possibilities of a species relatively new to the islands as a field crop was that of the 15-acre field of pigeon peas first planted in March, 1917. Over a hundred other forage crops were tested, but the test with pigeon peas seemed to combine more good points with less unfavorable characteristics than any other crops which have been under observation. The fields were cropped from three to five times for seed and forage. (See Pl. X, figs. 1 and 2.) The product was cured as hay, which in turn was milled into meal and fed to all classes of live stock. As a result of this demonstration conducted by the station a neighboring rancher planted 350 acres. Part of this planting is now being harvested, milled in a well-equipped milling plant, and fed extensively to live stock on his ranch. It is estimated that probably 1,000 acres were planted in the Territory during the past two years, most plantings having been with seed bred especially by the Haiku demonstration and experiment farm for seed yield and other good qualities.

Alfalfa variety inoculation and fertilizer tests.—Previous to the year 1907, several unsuccessful attempts were made to establish stands of alfalfa. Even where the soil was well prepared, the young seedlings succumbed before attaining a height of more than 4 inches. Heavy manuring would have helped somewhat to overcome the difficulty, but owing to the limited quantity available this means of fertilizing was impracticable. In January, 1917, a combined variety test, inoculation, and fertilizer experiment was inaugurated with 4 strains of ordinary alfalfa, 2 strains of Peruvian, 2 strains of Grimm, 4 strains of Siberian, and 1 strain of an alfalfa received under the name of Liscomb. Plats that received the pure cultures (commercial) of tubercle organisms showed no appreciable improvement over the checks. One ton of hydrated lime per acre failed to show any benefit. Sulphate of potash, applied at the rate of 250 pounds per acre, gave no beneficial results. The plats which received a combined application of 100 pounds each of dried blood and nitrate of soda gave a very poor growth, little, if any, better than the check plats, and the plants finally died, as was the case with the checks. Stable manure when applied at the rate of 20 tons per acre resulted in a fair growth. The best results were obtained from the plats which received an application of 500 pounds of a mixture of equal parts of reverted phosphate and superphosphate. From the start the growth and development were excellent, a fact which indicates clearly that the only need of the soils in question was that of phosphate fertilizers.

The applications of phosphate fertilizers were repeated in January, 1918, and again in January, 1919. Notes on the relatives merits of the different strains and varieties were made in connection with plats

receiving applications of phosphate fertilizer. The alfalfas were seeded January 3, 1917, at the rate of 8 pounds of seed per acre in drills 18 inches apart. A mixture consisting of 500 pounds of equal parts of reverted and superphosphate was applied in the drills at the time of planting. The soil was raw guava upland from which one plant and two ratoon crops of pineapples had been harvested. This is one of the most unfavorable types of soil and its history has not been such as to warrant putting the soil in good condition. The varieties are arranged in the order of their apparent merit under the conditions, the best being placed first. The hairy type of the Peruvian alfalfa proved to be a vigorous upright grower, which recovered quickly after each cutting. The yield was 28 tons of green forage per annum from 12 cuttings. The smooth type of Peruvian alfalfa blooms from four to seven days later, and gives from 10 to 11 cuttings per annum, with a yield of green forage weighing about 25 tons. This variety, because of its smoothness, is usually more favorably regarded than the hairy type. The ordinary alfalfa was represented by four regional strains (Texas, California, Utah, and Idaho). These all did well under trial. Their leafage is more dense and in habit they are more spreading than the Peruvian type. They mature later, also. An average of eight cuttings, aggregating 20 tons of green forage per annum, was obtained. The variety received under the name of Liscomb did not differ materially from the common alfalfa. The two strains of Grimm alfalfa proved to be slow growing, somewhat stunted in habit, with small dense foliage. The yield was about 10 tons of green forage per annum. Under ordinary conditions in the islands this variety can not be recommended for hay; however, it may prove valuable for pasturage, especially under somewhat unfavorable conditions at the higher altitudes.

The Siberian alfalfas (Cossack, Orenburg, Cherno, and Semipalatinsk) were placed under test. While they are of too spreading a growth to be well adapted for hay-producing purposes they may prove valuable as pasturage where grown under unfavorable conditions of soil and moisture, as at the higher elevations where any palatable legume that will survive is to be favorably regarded. In the variety tests the yield ranged from 10 tons of green forage for the Cossack strain to less than 5 tons for the Semipalatinsk. The Turkestan variety made a poor showing and its culture is not recommended.

Experiments with potatoes.—This year marks the close of a four-year field experiment with potatoes. This experiment included comparative tests of numerous varieties, together with fertilizer and cultural experiments. The ordinary Kula (Maui) potatoes were formerly noted for their fine quality and fairly abundant supply in the Honolulu market. During recent years, however, both the quality and quantity have decreased to a marked degree. With a view to

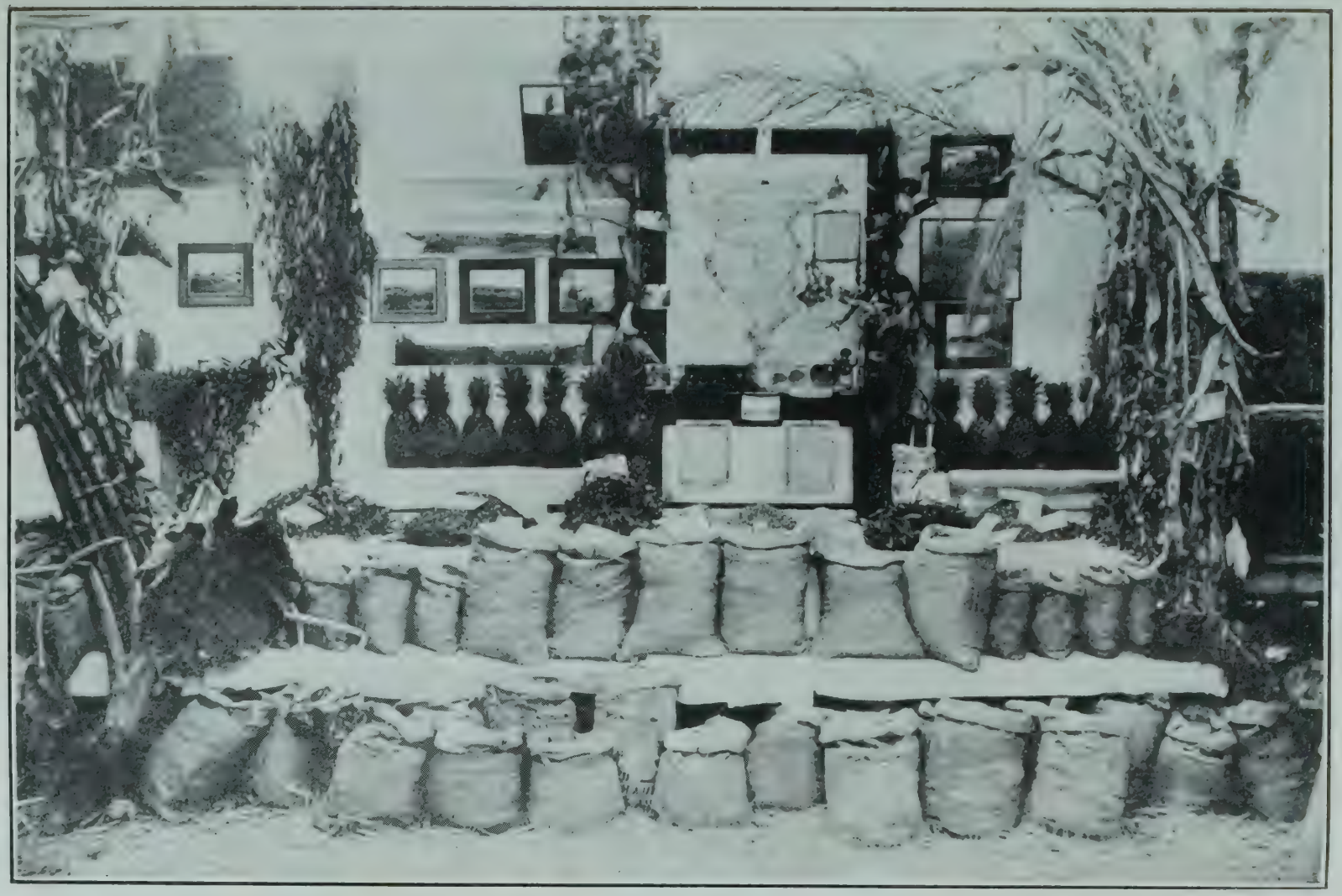

EXHIBIT OF PRODUCTS GROWN IN COOPERATION WITH THE STATION, SHOWING THE POSSIBILITIES OF THE DEVELOPMENT OF A 40-ACRE UNIT IN 5 YEARS. CORN, PINEAPPLES, PIGEON PEAS, TARO, SUGAR CANE, AND HOME-GROWN MIXED FEEDS FOR LIVE STOCK.

FIG. 1.—PIGEON PEAS INTERCROPPED WITH CORN. PEAS CONTINUE TO OCCUPY LAND FOR 3 TO 5 YEARS.

FIG. 2.—HARVESTING AND CURING PIGEON PEAS ON HAY-CURING RACKS. PINEAPPLES IN FOREGROUND ROTATED WITH PIGEON PEAS.

rehabilitating the growing of this important food crop, restoring it to its former status, and, if possible increasing its importance, there was instituted in 1915 a rather comprehensive series of potato experiments. It was clearly shown that the best tilth possible should be provided on rather heavy soils. In order to maintain a fairly mellow condition of the soil throughout the growing season it was found necessary to incorporate in the soil a liberal amount of organic matter. The most practicable method of doing this proved to be that of turning under one or two good crops of velvet beans or cowpeas. About 25 tons of green matter per acre, when turned under, will ordinarily suffice to supply the requisite amount of organic matter in the soil.

It has been found from experience covering four successive seasons' plantings that to secure profitable yields it is essential to supplement the green manure with a liberal application of commercial fertilizer. A comparative test of the standard chemical fertilizers available in Hawaii showed conclusively that the phosphatic fertilizers are the controlling factor in maintaining a high degree of soil fertility. It was also found that potatoes respond to such fertilizers as readily as do corn, alfalfa, and other crops which, without the application of phosphate in some form, are practically failures. An application of 500 pounds of either superphosphate or reverted phosphate, placed in the hills at the time of planting, gave an increased yield of from 150 to 400 per cent over the untreated plats. Finely gound bone meal also gave satisfactory results.

In planting potatoes the best results were obtained where 2-ounce seed pieces, bearing at least two eyes, were used, the planting being made when the newly sprouted shoots were about one-quarter of an inch long. The potatoes were placed to sprout in single layers in subdued light where they were kept fairly cool by suitably controlled ventilation. Before planting, the seed was treated for scab, the whole tubers being immersed in a solution of formaldehyde, 1 pint to 30 gallons of water. It was also found that 4 ounces of corrosive sublimate to 30 gallons of water made an efficient dip. The seed was planted at 18-inch intervals in rows 30 inches apart, thus giving 11,616 hills per acre. About 1,500 pounds of seed per acre was used. In moderately dry seasons, plantings were made at from 4 to 5 inches in depth, but in moist seasons the seed was planted from $2\frac{1}{2}$ to 3 inches deep.

One of the most critical problems in connection with the production of potatoes was that of eradicating the so-called blight and attacks from the recently noted mite and aphis. While these were responsible for considerable losses, methods have since been developed for safeguarding the crop by the use of Bordeaux-lime-sulphur spray

and nicotin preparations in adequate amounts. Such treatments add invariably to the cost of production, yet their very efficient results justify their use.

It is concluded that a lack of care in protecting the island's newly dug potatoes from sunshine is directly responsible for their poor keeping qualities. It is important that potatoes be placed in a cool dark storage as soon as they are dug. One of the varieties, when subjected to this treatment, kept in perfect condition for eight months. During the past two years the planting stock was grown from hill selected seed. The station's highest yielding variety gave an average yield of 1½ pounds per hill, but numerous hills yielded as high as 5 pounds of potatoes. It is regarded as fully established that carefully selected seed from individual hills will produce larger and more uniform crops than the general run of stock. The extension division has on hand a stock of selected seed potatoes of the New Era strain of Earliest of All, Producer, Snow, and White Rose. These are available for distribution to those planters who desire to test them, report on the results of the test, and, upon finding the varieties a superior kind, produce them in their own localities. The results of the potato variety test are shown in the table given below. No variety is included which for at least three seasons was not grown under field conditions. The range of yield in a variety during the different seasons has been as high as 40 per cent. The New Era Earliest of All yielded at the rate of 300 bushels to the acre, although the average yield was approximately 170 bushels per acre. During recent years yields as high as 170 bushels per acre under local conditions were very exceptional, even in the potato-growing districts of the island of Maui. In the Burbank varieties the low average yield was due to their late maturity and consequent susceptibility to blight and mites. These, on several occasions, have cut the crop short when otherwise an excellent yield would presumably have been obtained.

Results of potato variety tests at Haiku demonstration and experiment farm, showing approximate average yields, in pounds per acre, based on three or more crops.

Relative rank of variety.	Variety tested.	Approximate average yield per acre.	Relative rank of variety.	Variety tested.	Approximate average yield per acre.
		Pounds.			*Pounds.*
1	Earliest of All	10,200	13	Early Prizetaker	6,400
2	Producer	9,600	14	Gold Coin	6,200
3	Snow	8,350	15	Kula White	6,150
4	White Rose	8,100	16	Kula Flat	6,050
5	Bliss Triumph	7,700	17	Scotch Rose	6,000
6	Early Rose	7,600	18	Burbank, low top	5,950
7	Early Sunrise	7,400	19	Burbank, high top	5,400
8	Early Freeman	7,350	20	Burbank, Kula seed	4,650
9	American Wonder	7,250	21	Hamakua Hybrid (Kula, Kim strain).	4,000
10	Green Mountain	7,000			
11	Pride of Multnomah	6,500	22	Hamakua Hybrid (Yamata strain).	3,800
12	Netted Gem	6,150	23	Hamakua Hybrid (New Era strain	3,250

The division, basing its work on the results obtained in this variety test, is now using only the first five varieties listed, with the single exception of a select strain of low-top Burbank, which is to receive further trial. The earlier varieties, which usually escape the blight and mites, do decidedly better than the later-maturing sorts. After three years' effort, the selection work carried on to establish a variety immune to the blight has resulted in failure. It is thought that the best practice now available on Maui is that of growing early varieties best suited to the conditions and spraying them several times during the latter half of the growing season. These suggestions are made with special reference to the island of Maui, because there the conditions materially differ from those obtaining elsewhere in the Hawaiian Islands.

The cost per acre of growing a 100-bag (167 bushels) crop of potatoes at the Haiku demonstration and experiment farm was approximately $150. This includes rental of land, expense for tillage, seed, planting, harvesting, storage, etc. The crop, at present prices of $3.50 per 100 pounds, however, will be a profitable one if the yields produced by these best varieties can be maintained. When the yields fall to 50 bags (83 bushels) per acre, which is more than the average yield in the potato-growing districts of Maui, the profits are very small, although the cost of production is less there than in the Haiku section. A series of cooperative experiments in potato culture, the object of which is to demonstrate the most profitable methods of increasing the potato yield in those districts, is also in progress in the Makawao and Kula districts of Maui.

Pineapple experiments.—The pineapple experiments cover a tract of 10 acres; the first crop of this fruit was harvested at the close of the fiscal year. The experimental data, which require that each fruit be weighed as picked, necessitate as many as 2,500 individual weighings in the course of a single day's operations.

Tests with starch-yielding plants.—A considerable number of trial plantings were made with plants which, it is hoped, will ultimately become sources of commercial starch. These plantings included edible canna (*Canna edulis*), and several varieties of cassava, sweet potatoes, and taro. The observations, made in connection with a trip to the mainland during the year just closed, indicate the possibility of commercial production of starch on a large scale. Such an industry, once established in the islands, would constitute another of the diversified industries; and the residual product of these plants, after their starch had been extracted, would become an important source of economic carbohydrate stock feed.

REPORT OF THE GLENWOOD SUBSTATION.

By R. A. Goff.

The economical growing of food and feed crops continued to be the principal object of work done at the Glenwood substation during the past year. Purebred single-comb White Leghorn poultry was kept and eggs for hatching purposes were distributed throughout the island. While experiments with a number of promising crops were carried on, the work was mainly centered on potatoes, beans, cabbages, corn, and alfalfa. Unfavorable climatic conditions make it very difficult to produce many of those crops which are easily grown in other parts of the Territory. It was conclusively demonstrated that these five crops can be successfully grown in this district, and, in order to increase their yields, this station has tried to find better cultural methods.

The superintendent devoted much of his time to visiting homesteads and plantations in the Kau, Puna, Hilo, and Hamakua districts, assisting the farmer in every possible way by the distribution of seed and by imparting information, and in establishing fields of alfalfa.

The Glenwood substation, which was conducted principally with Territorial funds, received during the past year some assistance from the Federal Experiment Station in Honolulu, which paid the wages of two of its laborers.

IRISH POTATOES.

Three varieties of potatoes were planted, the Hamakua Hybrid (both red and white strains), the Portuguese Red, and Pride of Multnomah (an Oregon seed potato). The Multnomah, which consistently and repeatedly proved to be nonresistant to blight, has, therefore, been a failure in this district, where spraying is prevented by rains. The Hamakua Hybrid and Portuguese Red have made good yields. Marketable potatoes in yields of from 90 to 120 bags are usually obtained, and since they sell at from $2.35 to $3 per bag a good profit is usually realized from them. During extremely wet and cold years only one crop can be grown and the yields are lower, but in 1917 and in 1919 potatoes yielded well in this district.

In somewhat limited fertilizer tests with the Hamakua Hybrid, in which superphosphate and nitrate of soda, applied singly and in combination in varying amounts, and stable manure were compared, it was found that the use of equal amounts (250 pounds each per acre) of superphosphate and nitrate of soda was most economical.

SWEET POTATOES.

Twelve varieties of sweet potatoes, which were found growing in the Hilo and Puna districts, were planted. Of these five died and six grew slowly; the Laupuuwai, however, which made rapid growth and as yet has not been attacked by the leaf miner, is thought to be an excellent variety for this locality. The Madeira and New Era varieties produced well, but required over a year in which to mature.

MAUI RED BEANS.

The table below shows the results of a fertilizer experiment on eight plats, each 675 square feet, planted to Maui Red beans:

Results of fertilizer experiment with Maui Red beans

Plat No.	Fertilizer applied per acre.	Yield per acre.	Plat No.	Fertilizer applied per acre.	Yield per acre.
		Pounds.			*Pounds.*
1	Superphosphate, 500 pounds in 2 equal applications	1,400	4	Superphosphate, 250 pounds	1,195
2	Check, no fertilizer	780	5	Stable manure, 20 tons	1,800
3	Superphosphate, 500 pounds in 2 equal applications	1,235	6	do	1,975
			7	Check, no fertilizer	930
			8	Stable manure, 30 tons	2,030

It will be observed that stable manure gave the highest yields, but where a sufficient quantity can not be had for field planting, good yields may be obtained from the use of superphosphate alone.

DRY-LAND TARO.

Three varieties of taro, the Kuoho, Olaaoloa, and the Ala, were planted in February, 1919, and are doing better than any previously planted. The keiki, or sucker plants, are forming, and the crops should be ready to harvest by January, 1920. This is a somewhat longer growing season than is necessary at lower elevations, but a number of local growers have begun to plant taro where potatoes and cabbages do not thrive.

LICORICE ROOTS.

Roots planted in May, 1918, were a failure, since, after making a growth of three months, they died.

IMPROVED POHAS.

Records have been kept of the yields from the two plats of pohas which were planted in May, 1918. One plat contained the poha found growing wild in the woods; the other was planted to an improved giant variety obtained from Philadelphia. The native poha is perennial, and the pickings may be extended throughout the year.

The improved variety bears for a short season then dies. The native poha yielded 8 tons to the acre and the improved poha yielded 2½ tons to the acre. The improved variety is a much larger fruit, and, while only 40 pounds of the native poha can be picked and prepared for market in a day, over 200 pounds of the improved variety can be easily prepared. Both varieties make excellent jam. Where cultivation of the improved variety is unnecessary this fruit should become a paying crop.

ALFALFA.

In the substation plats alfalfa yielded from 20 to 30 tons of green feed to the acre and can be cut 9 times a year. The fields are still developing and should, after another year, produce even better yields. At lower elevations in the north Hilo district, fields, planted under the supervision of the superintendent and cut 11 times in 12 months, are growing stronger after each cutting. Various methods of planting were tried, but the one found most suitable to local conditions of climate and weed growth is that of drilling the seeds in rows 2 feet apart. After 6 months' time the plants usually cover the ground and check weed growth, so that rather infrequent cultivation is required. When growing alfalfa it is very essential to have the fields in which it is to be planted as nearly weed-free as possible. The substation is keeping track of the costs of planting and bringing the crop to the first cutting stage, but as yet these data are not complete. Cooperative experiments in the planting of alfalfa were started in 12 localities on the east side of this island and so far are promising.

SWEET CLOVER.

Sweet clover is a slow-growing plant in this district, is not seriously attacked by insects, and produces nearly as well as alfalfa. It is an excellent feed for dairy cattle, grows on soils too poor for other legumes, and when turned under enriches the soil.

CORN.

Three varieties of corn, Waimea White, Guam, and Cuban Red, have given good yields, the Waimea White doing the best of the three. In the Glenwood district stable manure is a splendid fertilizer for fields planted to corn, and phosphate fertilizer gives almost as good results. In a comparative fertilizer test with Waimea White, stable manure gave a yield of 2,600 pounds of corn to the acre; phosphate, applied just before planting, at the rate of 400 pounds to the acre, gave a yield of 2,415 pounds of corn. Nitrate of soda and complete fertilizers, which are more expensive than phosphate, gave lower yields and can not be recommended. The average yield per acre of the three varieties was as follows: Waimea White, 2,415 pounds;

Guam, 1,650 pounds; and Cuban Red, 1,200 pounds. Guam corn doubtless would do as well as or even better than Waimea White at lower elevations, and Cuban Red, which has the advantage of being hardier and more resistant to pests, can be grown where other varieties do not give good yields.

SORGHUM.

Texas Blue Ribbon, Early Amber sugar cane, kafir, Egyptian wheat, and feterita were planted in order that a green feed for dairy cows might be secured. It was known that these would ratoon and in this way eliminate the necessity of replanting after each crop. Because of heavy rains it is often difficult to plant corn in the proper season, and if the sorghums can be made to ratoon well, they will prove of inestimable value to local dairymen. In Hawaii all of these varieties mature seed which probably would become a source of poultry feed were some method to be found which would prevent birds from eating the maturing grain. The crop, secured from planting seed, averaged 22 tons of green feed to the acre, but the ratoon crops so far have been stunted and have not been used for fodder because of the possibility of their poisoning the cattle. As the sorghums continue to ratoon after each cutting, different fertilizers are being applied in an effort to secure a quick-growing, heavy second growth.

EDIBLE CANNA.

The edible canna which was introduced as a substitute for potatoes is now more largely used as a hog feed. At this elevation it produced 7 tons of roots to the acre with a nine months' growing season, but matures more quickly at lower levels. When well fertilized, the tops grow to a height of 8 or 9 feet; these tops, after being cut in 6-inch lengths, are fed by local growers to hogs. The roots as well as the tops are relished and furnish a large part of the ration; the latter, when mixed with 2 pounds of soured rice bran, cause the hogs to steadily increase in weight. Small fields of canna are kept growing at the substation and cuttings are distributed among homesteaders.

CASSAVA.

Cassava, from which tapioca is made, makes a rapid growth in the Puna district of this island. Cuttings were secured from that place and planted at the substation in the late autumn of 1917. It failed, however, to reach the size of plants 5 months old at the lower elevation. Waialua White and Trinidad varieties were also planted and are maturing slowly. A very good grade of edible starch can be made by grating the roots, and, after mixing them with water, straining them through cheesecloth. The value of these roots as a hog feed

is being recognized by many growers to whom cuttings were distributed.

PIGEON PEAS.

Pigeon-pea bushes grow to a height of 5 and 6 feet in the substation plats, and, although they do not mature seed, their younger branches, when cut off and ground, furnish a palatable feed for dairy cows. Since they are legumes, they have the added advantage of enriching the soil, especially when turned under as a green manure crop. Seed which was distributed to farmers in the vicinity of Hilo has developed into plants which are now bearing seed. The pigeon-pea crop is highly prized by those who have raised it.

GRASSES.

Demonstration plats of Kentucky blue, awnless brome, redtop, timothy, orchard, crested dogstail, Italian rye, and meadow fescue grass, planted in 1917, continued to grow well throughout the year. Originally planted in rows 3 feet apart, the redtop and Kentucky blue grass have spread until they now cover the ground and form a heavy mat; this feature makes the grasses valuable additions to the pastures of this district. Less than an acre of *Paspalum dilatatum*, or Australian water-grass, which was planted in 1916 from roots set in 2½-foot rows, furnishes all of the grazing needed for one dairy animal, since it has spread until the ground is almost entirely covered. Six acres of the native or wild grass is necessary to supply grazing land for one animal, so that Paspalum is easily worth five or six times as much as the grass found in the majority of local pastures. This station secured seed of these grasses for local dairymen who desired to improve their pastures. Twelve varieties of grasses and leguminous plants from Florida were planted in the field and in flat boxes, but failed to germinate.

POULTRY.

Purebred single-comb White Leghorn poultry has been kept, and eggs for hatching were distributed throughout the island at a nominal price. The entire flock netted a return of 26 cents per bird per month above cost of feed. At the same time, the flock supplied the hatching eggs used at the station and paid for the feed used by over 300 growing chicks. The hens of the entire flock average 12 eggs per month. The feed cost of each hen is 30 cents per month; the return above feed cost, when the eggs are sold on the market, is over 40 cents per bird. It has cost the station 85 cents on the average to bring a pullet to the age of 3 months, exclusive of the labor required, and about $2 to care for it until the time of laying. Poultry raising should become profitable in the Territory where small flocks are kept as a side line or in larger flocks of about 500.

COOPERATIVE EXPERIMENTS.

After demonstrating in experiment plats that phosphate fertilizers as well as complete fertilizers return large yields of potatoes per acre, arrangements were made with a Glenwood farmer to carry on a cooperative fertilizer experiment on his land. An acre was divided into eight equal plats to one of which a complete fertilizer was applied by the farmer at his usual rate of application. Another plat was reserved as a check plat where no fertilizer was applied; and in the other six, reverted and superphosphate were applied by the substation at the rate of 250, 500, and 1,000 pounds per acre. A second application of 150 pounds per acre was given to the plats which had received 250 pounds. The potato rows were about 40 inches apart and the fertilizer was applied in the rows and not scattered broadcast. At harvest time it was found that all the fertilized plats returned a 30 per cent larger yield than the check, and that the plats in which 400 pounds of phosphate had been used gave as large yields as the one in which the more expensive complete fertilizer had been used. Practically all of the potatoes planted in Glenwood this year have been fertilized with phosphate at a considerable saving to the planters as a result of the experiment, and all indications point to a larger yield than in previous years. The superintendent has ordered all the phosphate for the local growers, and will continue to do so until satisfactory arrangement for their purchase can be made with local dealers. On various farms demonstrations were also made of the use of poisons for cutworms, cabbage worms, potato blight, and sweet-potato leaf miner. Assistance was given to homesteaders in the purchase of reliable seed and poison for the various pests.

SCHOOL-GARDEN CONTESTS.

The superintendent acted as judge in the Star-Bulletin school-garden contest in the districts of Puna and Kau and in the final judging in the Kona district. He also served as judge in the Hilo Board of Trade home-garden contest.

BOYS' WORKING RESERVE.

The superintendent for four months acted as county director of the Boys' Working Reserve work on this island and for nine months had charge of the work on the east side. A trip was made around the island of Hawaii with G. A. Young, the executive secretary of the reserve in the Territory; a motion-picture machine was used to give exhibitions, and in each of the districts a practical talk was given.

HAWAII AGRICULTURAL EXPERIMENT STATION,
HONOLULU, HAWAII.
J. M. WESTGATE, Agronomist in Charge.

Under the supervision of the STATES RELATIONS SERVICE,
Office of Experiment Stations, U. S. Department of Agriculture.

REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION.

1921.

Issued, September 12, 1922.

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HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU.

[Under the supervision of the States Relations Service, United States Department of Agriculture.]

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NELLIE A. RUSSELL,[2] *Collaborator in Home Demonstration Work.*

LETTER OF TRANSMITTAL.

HAWAII AGRICULTURAL EXPERIMENT STATION,
Honolulu, Hawaii, July 22, 1921.

SIR: I have the honor to transmit herewith and to recommend for publication a report of the Hawaii Agricultural Experiment Station, 1921.

Respectfully,

J. M. WESTGATE,
Agronomist in Charge.

Dr. A. C. TRUE,
Director States Relations Service,
U. S. Department of Agriculture, Washington, D. C.

Publication recommended.
A. C. TRUE, *Director.*

Publication authorized.
HENRY C. WALLACE,
Secretary of Agriculture.

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[1]Appointed July 1, 1920. [2]Appointed on part-time basis Nov. 1, 1920.

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REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION, 1921.

SUMMARY OF INVESTIGATIONS.

By J. M. WESTGATE, *Agronomist in Charge.*

INTRODUCTION.

During the fiscal year 1921 the station continued to devote the major part of its energies toward the development of investigations which it is thought will assist most tangibly in furthering the diversified agricultural industries of the islands. Both the sugar-cane and the pineapple industries have developed to such an extent commercially that their producers are now able to finance private experimental work. The smaller industries, however, not yet having reached this financial stage, are still dependent upon the station for experimental work that must be done to enable them to develop to desirable proportions. The rice, banana, and starch-producing industries are all deserving of and receiving special attention and interest, because they furnish staple food supplies which can be exported in normal times and used to feed the local population in the event of interruption to shipping. The station is also giving attention to the production of taro, which is one of the staple food crops of the native population.

On account of the extremely high prices obtaining in 1919 and 1920 for sugar and pineapples, the area planted to these crops was increased during the year and a proportionately less acreage was left for the production of the diversified crops. The new areas are largely the upper lands that had not been devoted to crops of any kind owing to lack of water for irrigation and the expense of clearing the guava and lantana bushes covering them.

The station continued to make experiments in drying and canning local fruits and vegetables for the purpose of eliminating the waste of certain perishable food products and of furnishing a profitable outlet for their utilization when the fresh materials are out of sea-

son. These experiments are deemed necessary because the local demand for any food product is limited, and a slight overproduction usually gluts the market, resulting in waste. Experiments were also undertaken for the production of starch from such plants as edible canna, tree fern, cassava, sweet potato, Irish potato, and banana.

BUILDINGS AND GROUNDS.

During the year some landscape gardening was done on the station grounds. This work included the shifting of inconveniently routed roadways and the planting of hedges and ornamentals. A number of the station buildings received their first coat of paint since before the World War, and the photographic dark room in the horticultural building was refitted, special equipment being installed for taking natural-size photographs of fruits and other products.

MAUI COUNTY AGRICULTURAL FAIR.

The third annual Maui County Agricultural Fair, which was held from October 21 to 23, inclusive, again emphasized the diversified agricultural features of the islands, especially the production of fruits, vegetables, and various kinds of feed for live stock. The station made exhibits of some of the salient features of its work along horticultural, agronomic, and extension lines. A representative of the station was in charge of the booth at all times to answer questions. Many people were interested in the work of the station and numerous requests were received for planting stocks of improved varieties of farm crops, vegetables, and fruits.

HORTICULTURAL INVESTIGATIONS.

The appointment of Willis T. Pope as horticulturist of the station resulted in some change in the projects of the horticultural division, although the older and more permanent investigations were continued essentially as outlined in the past. Among the latter investigations are those with bananas, papayas, mangoes, avocados, and citrus fruits, special attention being given to the production of bananas, avocados, and papayas, which have high commercial value at the present time. New areas are being opened up for the production of bananas, and plans are under way for the utilization of the smaller bunches which are not adapted to shipping. It is planned to convert them into edible fruit products by drying or other process, so that they can be either shipped or used locally.

In the work with avocados there have been developed combinations of orchard plantings which will make possible the gathering of these fruits every month in the year. Owing to its high oil content, which varies from 8 to as high as 29 per cent, the avocado

fruit is difficult to preserve in a palatable condition. However, there is some possibility of success along this line, and it is also likely that a satisfactory salad oil can be manufactured from the fruits that can not be more profitably utilized.

During the year the viticultural experiments were transferred from Wahiawa, on the island of Oahu, to the station grounds at Honolulu. A number of varieties of promising grapes have been obtained, including the famous Corinth seedless grape, which is the source of most of the dried currants of commerce. This variety may prove of great value to the Territory, especially if it can be made to produce satisfactorily on the otherwise unused steep slopes and ridges which are numerous throughout the islands. Such conditions are said to be similar to those in Greece, where the currant grape has been under cultivation for many hundreds of years.

Experiments with numerous varieties of pohas, the local name of the husk tomato or ground cherry, indicate that no variety is so desirable for jam making as the wild poha (*Physalis peruviana*) of the mountainous districts.

The horticultural division has kept in touch with the public by means of the local press and by numerous distributions of propagating material of improved fruits and vegetables. In one instance, the publishing in a local newspaper of a brief article concerning the planting material which could be had at the station on a certain day resulted in 121 personal calls during that day for the planting material, together with numerous inquiries by letter for plants, cuttings, and seeds.

AGRONOMIC INVESTIGATIONS.

Agronomic investigations, as in the past, were directed principally to the further production of various field crops for animal and human consumption. The distribution of seeds, cuttings, and tubers of improved varieties continued to be an important phase of the division's activities. The variety tests of sweet potatoes, Irish potatoes, and taro were continued both at the central station and in cooperation with a number of ranches and plantations. The grain investigations were confined largely to corn, and an especial attempt was made to hybridize the white Guam corn with some yellow varieties to obtain a variety having the desirable characteristics of the Guam corn and the yellow color demanded by the local market. A very satisfactory start has been made in this experiment and there have been obtained yellow ears of the desired type which it is hoped will be possible to fix by rigorous selection. A number of other varieties of corn have been under test, but none seem to do as well at low elevations as the Guam and Cuban varieties. Tests

were made with sweet corn, the varieties Pocahontas Early, Henderson Sweet, and Golden Bantam giving promising results at the central station. Most varieties of sweet corn do not succeed at the lower levels in the Hawaiian Islands.

The local production of forage crops continued to be an interesting and important line of work, and the soiling crops which received the most attention were Napier or elephant grass (*Pennisetum purpureum*), Merker grass (*P. merkeri*), and Uba or Japanese sugar cane. These crops are proving valuable at the local dairies, and also on the plantations where up-to-date dairies are being installed to supply the laborers with milk for their families. Of the legumes, the kudzu vine (*Pueraria thunbergiana*) received the most attention. Cuttings of this vine have developed into large-sized, vigorous plants at the station much more rapidly than have seedlings. However, it is likely that the vigor of the plants grown from cuttings was due to some inherent character in the plant, and not to the planting of cuttings.

POULTRY WORK.

Owing to the numerous demands made upon the station for assistance in solving the many problems arising in connection with the poultry industry, the station deemed it necessary to devote some attention to this line of work. There is no poultry plant at the station, but feeding experiments and demonstrations were carried on with the flocks of various members of the staff. It is felt that a large amount of experimental work will have to be carried on with poultry before the numerous problems now confronting poultrymen in Hawaii can be solved.

CHEMICAL INVESTIGATIONS.

The work of the chemical division during the year was largely devoted to carrying to completion experiments that had been started during the previous year and to the launching of a new experiment having for its object the utilization of tree-fern starch. This product has many qualities to commend it. When cooled it has that opalescent appearance so characteristic of arrowroot. It has a clear, smooth consistency and a palatability and variety of uses that should make it a ready sale.

The analysis of Hawaiian starches and residues therefrom indicate that starch of excellent purity for household use can be prepared from Hawaiian root crops with simple, inexpensive apparatus. However, there is need for further study to determine the most effective methods of shredding and extracting because of the high starch content of the residues.

Cooperative fertilizer experiments with large growers were carried on with pineapples, bananas, upland sugar cane, and pigeon peas.

An experiment undertaken for the control and eradication of the pineapple wilt was concluded during the year. This was an attempt to find some disinfectant which when applied would kill the attacking organism without vitally injuring the pineapple plant. The test failed to reveal a satisfactory disinfectant or combination of disinfectants.

Preliminary investigations were begun to determine the resistance of various local crops to varying amounts of salt in the irrigating water. Sufficient progress has not been made to permit of a report this year.

AGRICULTURAL EXTENSION WORK.

The work of the extension division was carried on along essentially the same lines as in past years. The resignation of the superintendent of extension, effective early in the next fiscal year, has necessitated the closing up of certain lines of extension activity which he is particularly adapted to manage. The operation of his personally owned farm as a demonstration and experimental farm will necessarily cease. Fortunately, however, the experiments have been carried to a practical consummation during the seven years the farm has been in operation. This farm has served as a model to all the homesteaders in the islands and the demonstrations have been beneficial to the small farmer and the large plantation owner, both of whom have frequently called upon the superintendent for his advice and assistance.

The further aim of the extension division is to develop club work for boys and girls, as well as cooperative organizations to solve the problems connected with marketing and shipping, to stabilize and standardize market products, and to study the market requirements. It is very evident that the problems of marketing farm crops are just as important as are those connected with the production end of the farming business.

The collaborators have continued to give satisfactory service in acting as representatives of the station in their respective districts and in lending their influence to the various agricultural activities which needed developing. The superintendent of extension acted as adviser to many of the up-to-date plantation owners who were endeavoring to develop a number of dairy projects. These men realize the advisability of supplying large quantities of wholesome milk to the growing families of their employees, and consulted the superintendent regarding the best breed of dairy cattle for Hawaiian conditions, the most profitable equipment for the dairy, and the

best method of planting fields for the continuous production of nutritious forage for cows.

The swine industry received attention, and emphasis was laid on the adaptability of the Berkshire breed to island conditions. The herds of hogs at the Haiku substation and demonstration farm served to demonstrate the possibilities of this breed.

An important feature of the extension work during the year was a series of lectures and demonstrations given in cooperation with other local agricultural agencies on the islands of Hawaii, Kaui, and Maui.

HOME DEMONSTRATION WORK.

Home demonstration work was started on a small scale by an experienced home economics demonstrator who worked part time as collaborator. Hawaiian fruits and vegetables, canned, preserved, and made into jams, jellies, and marmalades, were collected for exhibition and demonstration purposes. This collection was given wide publicity, some of the material being exhibited in the leading stores. Cooking demonstrations were held at various women's clubs and other organizations. Demonstration meetings were held in Honolulu and also on the sugar plantations for the benefit of the wives of the plantation employees who did not find it convenient to attend the demonstrations given in the more densely populated centers.

EXTENSION WORK ON THE ISLAND OF HAWAII.

The extension work of the island of Hawaii, the largest island of the group, is under the immediate charge of the extension agent for that island. During the year the agent was able to keep in reasonably close touch with all the lines of diversified agricultural activity. He also assisted the small farmer in making trial shipments of bananas from Hilo to San Francisco direct and by way of Honolulu. In addition to his other activities the extension agent acted in the capacity of general superintendent of the Glenwood demonstration farm, which is operated by a collaborator living on the farm. The work of this farm was directed principally to the raising of poultry to determine by selection the best egg breeds for Hawaiian conditions. A flock consisting of 300 laying hens was trap nested[1] so that it might be learned which varieties are the best layers, and eggs from the best hens were sent for settings to homesteaders and poultrymen in various parts of the islands of Hawaii, Maui, and Oahu. A small herd of Berkshire pigs is being maintained at this farm, together with a dairy herd, which was materially increased by births during the year.

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[1] A trap nest is one so arranged as to confine a hen after she enters until she is released.

Demonstrations in budding and grafting seedling fruit trees with improved varieties were popular phases of the work of the year. In connection with the forage crop extension work, plats for demonstration purposes were planted in alfalfa, elephant grass, and pigeon peas, the plantings being made mostly on plantations where dairies are being installed.

The school and home garden activities were again successfully carried on. Attention was given to the agricultural phases of the boy scout work, and demonstrations of various kinds were made for the benefits of those boys who were working for the merit badge in agriculture.

HAIKU SUBSTATION AND DEMONSTRATION FARM.

At the Haiku substation and demonstration farm large plat demonstrations were made and a great amount of experimental field work was carried on. Special attention was given to the growing and feeding of new and improved forage crops which gave the best results in comparative tests made at the central station. The principal forage crops under test were the Yellow-Tipped cane, Uba cane, Napier or elephant grass, and Merker grass, all of which make desirable dairy feeds when they are cut and fed in the green stage.

Pigeon peas.—The distribution of pedigreed farm seeds continues to be an important phase of the station's work. During the year enough seed of the improved pigeon peas was distributed to responsible growers to plant 4,000 acres. This distribution was made by people who obtained the original seed stocks from the Haiku substation.

Sugar-beet work.—A variety test was made with beets during the year to determine their yield and sugar content, which was found to be high.

Pineapple experiments.—Experiments with pineapples have been under way since 1914. From them a great deal of valuable data have been obtained for the use of pineapple growers and packing companies. The experiments included both fertilizer and cultural investigations, and have shown that the type of soil and its humus and drainage conditions have more to do with the maximum production of the pineapple plant than have the kind and amount of fertilizer used.

Tests with starch-yielding plants.—Experiments with such root crops as edible canna (*Canna edulis*), cassava, sweet potatoes, and Irish potatoes were made to determine their value as starch yielders. Among other things it was found that the waste products remaining after the starch has been extracted make very good constituents of mixed feeds for farm live stock, and also that 5,200 pounds of these

starch residues have a feeding value equal to that of 2,000 pounds of shelled corn.

Live-stock work.—The live-stock work of this station includes breeding and feeding experiments with goats, swine, and dairy cows. The breeding animals are frequently loaned to interested farmers in various parts of the islands for the purpose of upgrading their stock. It is hoped that the station's purebred Toggenburg buck will be effective in materially building up the virile native stock as milk producers.

MISCELLANEOUS SUBSTATIONS AND DEMONSTRATION FARMS.

The station maintains substations on the islands of Hawaii, Oahu, and Maui for the purpose of carrying on work which can not well be undertaken at the central station. The Glenwood substation and demonstration farm, on the island of Hawaii, is being operated as a poultry, pig, and dairy farm, and the Tantalus substation, on the island of Oahu, for the purpose of obtaining data concerning the behavior of crops, especially tropical fruits, at a higher elevation (1,000 feet above sea level) than can be had at the central station. The Haleakala substation and demonstration farm on the island of Maui has made numerous variety tests with corn, potatoes, and other farm crops. The pigeon pea is proving especially valuable as a poultry feed and as a protection to poultry from the wind and sun.

REPORT OF THE HORTICULTURAL DIVISION.

By W. T. Pope.

INTRODUCTION.

The principal work of the division of horticulture included the reorganization of the projects which have been in progress during the past few years, and which were found to be of special importance during the World War, when immediate food production became a pressing problem. This division is now turning to the more general plan of work formerly followed by the station in its effort to improve horticultural practices throughout the Territory.

Some leading points in this plan are the introduction of new plants which it is hoped will prove of economic value in Hawaii; an endeavor to improve the useful plants that are already growing on the islands; and the propagation and distribution of new and improved plants and seeds to people wishing to grow more and better fruits and vegetables. The work of the year was enlarged by the dissemination of useful information that was gained by experiments and otherwise. This has involved many interviews and the preparation

of manuscripts for printed circulars and newspaper articles dealing not only with direct horticultural problems, but with associated subjects, such as plant diseases and insect enemies.

Many things indicate a growing interest in agriculture in Hawaii. For instance, the number of requests for plants and seeds, which the station has for distribution in connection with the experimental work, is far greater than can be supplied. No doubt this increasing interest is due in part to the reduction in plant loss caused by insect pests. The changed conditions brought about by the World War have been the means of convincing many people of the necessity of increasing the food crops and the advisability of maintaining a home garden for the production of fruits and vegetables for home consumption.

AVOCADOS.

Avocado investigations at the Hawaii station have been in progress practically since its establishment in 1901. Some of these experiments have brought to light very valuable information, a considerable part of which was published as a bulletin of the station.[2]

At the present time there is a wider interest than ever before in the growing of this fruit, both in tropical America and on the mainland of the States. Doubtless the demand for a more diversified food production has resulted in giving more time to the study and culture of this useful fruit. Recent investigations made by the United States Department of Agriculture, through its plant explorers, have revealed many facts regarding the possibilities of the avocado, some of which were formerly unknown in the States.

The composition of the avocado varies greatly with the variety, as is indicated in the following table:

Composition of avocado varieties under test at the Hawaii station.[1]

Variety.	Water.	Protein.	Fat.	Carbohydrate.	Ash.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Trapp	78.66	1.61	9.80	9.08	0.85
Solano	90.62	1.27	3.64	3.64	.62
Northrop	66.31	2.36	23.00	7.12	1.21
Harmon	71.58	2.50	19.33	5.32	1.27
Fuerte	60.86	1.25	29.14	7.40	1.35
Puebla	63.32	1.80	26.68	6.64	1.56
Taft			18.50		

[1] From California Sta. Bul. 254, and other sources.

Individual trees possess widely varying characters, such as different seasons for fruiting in different localities of the same country, and different sizes, shapes, and flavors of fruit. These characters will probably lead to the standardization of varieties of quality for ex-

[2] Hawaii Sta. Bul. 25, The Avocado in Hawaii.

tensive use. The avocado is believed to have a fairly high food value, and is considered to be one of the greatest sources of food produced in the Tropics at the present time. In Central America it is used extensively as a substitute for meat.

Wilson Popenoe, plant explorer of the Bureau of Plant Industry, United States Department of Agriculture, estimates that the total area devoted to avocado culture in California, Florida, Cuba, and Porto Rico approximates 1,000 acres. In California the avocado growers have formed a cooperative organization for the purpose of carrying out their work more efficiently. Many varieties have been tried, and those of fine quality have been recommended for planting. During the summer and autumn avocados are regularly found on the markets of several of the larger cities in the States, and their value as a highly nutritious fruit is rapidly becoming known.

Conditions for avocado culture were unsatisfactory at the central station, and the plantings of recent years have been transferred to the Tantalus substation, where the climate is cooler and the rainfall greater. Moreover, the soil is deeper and richer at the latter place, and the elevation is about 1,000 feet. The first plantings were made over two years ago and have been extended from time to time. The trees in this orchard include many local varieties and 22 varieties of the Popenoe collection in Guatemala. Young budded trees are being developed from budwood that was recently obtained from the Bureau of Plant Industry, United States Department of Agriculture. The varieties represented in this collection are in part those that have gained a reputation in Florida and California for their hardiness, productiveness, and choice qualities of fruit. Some excellent additions in both local and foreign varieties have been furnished the station by interested citizens.

The objects of the avocado investigations are (1) to determine the best conditions for the culture of the avocado in the Hawaiian Islands; (2) to test a number of varieties with the hope of being able to select a group maturing high-grade fruit throughout the year; (3) to encourage the culture of budded varieties so that there will be established a standard fruit for commercial purposes as well as for the home orchard; (4) to determine by experiment the best methods of control of insect pests and plant diseases; and (5) to solve the cause and determine a remedy for the untimely dying of avocado trees in many parts of the islands.

AVOCADO CLASSIFICATION.

The station has made a start in the classification of avocados, using the system established by Popenoe.[3]

[3] Manual of Tropical and Subtropical Fruits.

The genus Persea, to which the avocado belongs, is a member of the laurel family (Lauraceæ), and is related to the cinnamon tree, camphor, and sassafras.

Careful study of cultivated avocados show that they are derived from two species which are briefly described as follows:

Persea americana, which is also know by some authorities as *P. gratissima*, includes all the varieties known horticulturally as belonging to the West Indian and Guatemalan races. This species is the common avocado of the tropical American lowlands, and the one which has been most widely disseminated throughout the Tropics. Most avocados in the Hawaiian Islands belong to it.

Persea drymifolia, designated by some as *P. americana* variety *drymifolia*, includes the small avocados of the Mexican highlands. This great group has been cultivated to very little extent in other countries, and only very few trees of the group are to be found in Hawaii.

A third species, *P. schiedeana*, commonly known in its native country as the "coyó," or "chinini," is of recent introduction. It is indigenous in southern Mexico and a part of Guatemala, and as yet is of no consequence outside of these countries. A sample tree is now growing at the Hawaii station.

Seedling avocados of the above-mentioned species vary in habits of growth, particularly in relation to the fruit. The fruit of the common avocado (*Persea americana*) varies greatly in size, shape, color, and quality.

Variations in the *P. drymifolia*, the Mexican race, are most marked in the small size of the fruit and the anise-like odor of the leaves.

These species as cultivated in parts of the States are horticulturally grouped into three races or species, based on certain well-marked, differentiating characters which propagate true to seed, with possibly the exception of simple fluctuating variations. The classification of avocados into these three races is useful because it brings together all of the varieties having several characters in common. In fact, the mere statement that an avocado belongs to the West Indian, Mexican, or Guatemalan race gives the idea of the relative hardiness, season of ripening, and commercial characters of the fruit. The key to the racial characters of the two important species follows:

(1). *Persea drymifolia:* Mexican race. Leaves anise-scented; skin of fruit thin (rarely more than one-thirty-second inch thick).

(2) *Persea americana:* Leaves not anise-scented; skin of fruit thicker (from one-thirty-second to one-fourth inch thick:

(*a*) Fruit, West Indian race. Summer and fall ripening; skin usually not more than one-sixteenth inch thick, and leathery in texture.

(*b*) Fruit, Guatemalan race. Winter and spring ripening; skin one-sixteenth to one-fourth inch thick, and woody in texture.

AVOCADO DIE-BACK.

The cause of and the remedy for the early death of avocados in the islands has been much discussed but the losses continue as heretofore. The complaints of losses of trees are very frequent. The chief symptoms of trouble are briefly: (1) The dying back of branches, resulting in the death of the tree[4]; (2) in most cases the leaves turn yellow and drop off, the green branches wilt, become hollow at the pith, turn brown, and slowly die back into the trunk; (3) the roots when examined have a lifeless appearance; and (4) often trees die quickly when they are laden with fruit.

The disorder is not necessarily confined to the avocados of Hawaii. It has recently been reported as a common malady of the avocado on the island of Tahiti and also on other islands of the Pacific.

Die-back of the avocado has been overcome to some extent in the milder forms of attack by pruning out the dead parts of the top and feeding the roots thoroughly rotted barnyard manure and an increased supply of water. The present indications are that the difficulty is due to a combination of causes. In the first place, the avocado is what may be called a tender tree, because it is susceptible to disorders if conditions are not right. It can not stand poor soil conditions, such as poor soil drainage, too much volcanic sand or a layer of rock, or an insufficient water supply in dry weather. The greatest number of trees are lost during dry periods of the summer. Die-back may be prevented by giving the trees good culture, taking care to plant them in a location that is not only well sheltered from hard winds but that has a soil rich in organic matter and a good underdrainage.

COOPERATIVE EXPERIMENTS.

Avocado experiments made in cooperation with private growers were started in 1919 and 1920 and are still in progress. Several of the plantings are doing very well and others have not made satisfactory growth.

AVOCADO VARIETIES UNDER TEST.

Many varieties of avocados are under test at the central station and at the Tantalus substation, a mile up the mountain from the central station. Among them is a new variety of great promise, the Taylor (station No. 4639), the origin of which is a seedling growing in the Kaimuki district, Honolulu. (Pl. I, Fig. 1.)

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[4] Die-back may begin at any age. It occurs most commonly about the time the young trees first come into bearing. It has not been traced to insect pests, nor to any sort of plant disease.

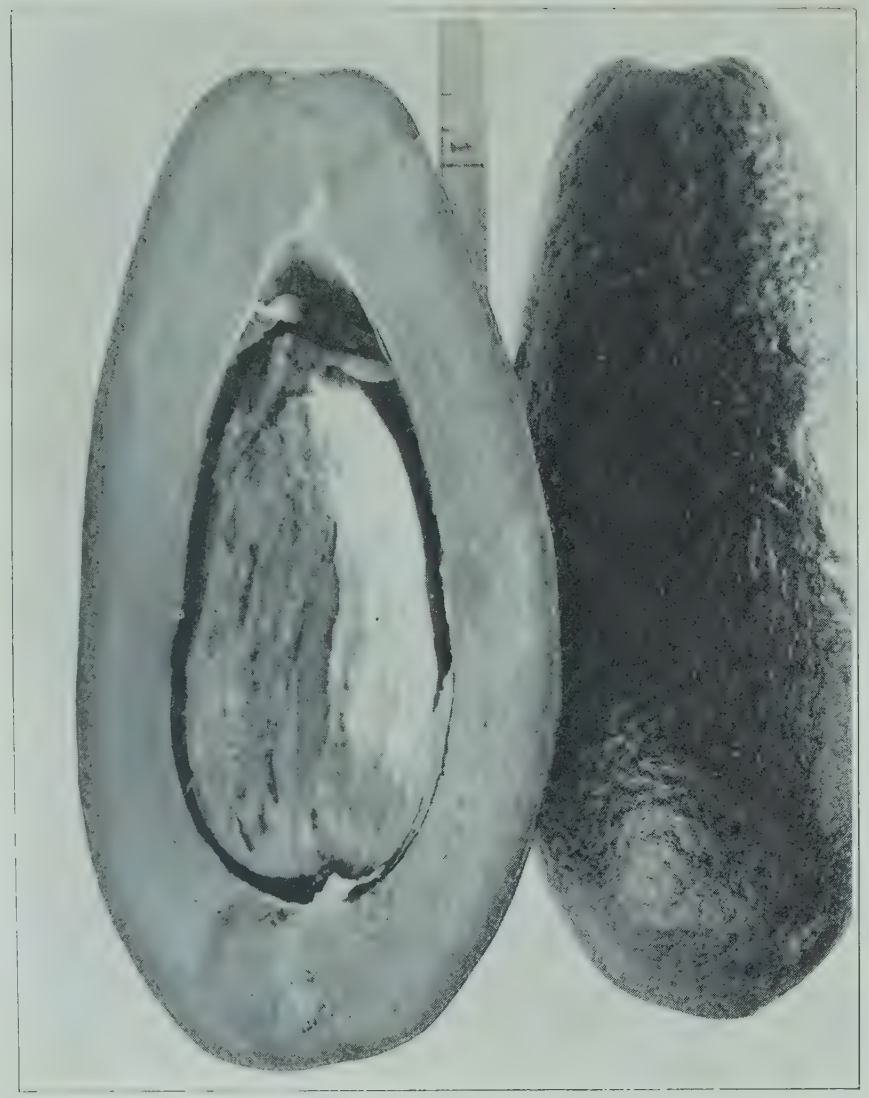

FIG. 1. TAYLOR AVOCADO. A SEEDLING GROWN AT KAIMUKU, OAHU.

FIG. 2.—CLUSTER OF MACADAMIA NUTS APPROACHING MATURITY.

FIG. 1.—DWARF PAPAYA FROM ROOT CUTTING. GROWN BY MRS. DELLA SHAW, MANOA VALLEY, OAHU.

FIG. 2.—GRAFTED PAPAYA TREE, 4 MONTHS AFTER GRAFTING. STATION GROUNDS.

BANANAS.

The Hawaiian Islands have many advantages for the growing of bananas. Both the soil and the climate are admirably adapted to the cultivation of this highly nutritious fruit; the Territory is free from tornadoes which do considerable damage to banana plantations elsewhere, and the winds are seldom so strong as to blow the plants over; and the plant as it grows in these islands has very few enemies such as diseases and insect pests. This fruit is one of the most extensively used tropical fruits in the Temperate Zone and has a wide range of uses in its natural clime. Many varieties are grown in Hawaii, some of which are hardly profitable for shipping to the cooler climates.

Banana growing as an industry in Hawaii dates back to about 1864, when the first exportations were made. Since that time the industry has made slow growth, but the commercial production now amounts to about 200,000 bunches annually. The industry has been seriously handicapped in the past by the lack of proper shipping facilities. The development of proper shipping facilities has been retarded by the competition which the fruit has met with in the markets of the mainland where Central American grown bananas are sold. The local industry has remained relatively small. The plantings are increasing, however, and the demand for offshoots is greater than the supply. From $25 to $50 per 100 is being paid for them. Offshoots of some of the commercial varieties can not be obtained on the market.

Investigations were undertaken by the station for the purpose of improving the banana industry in every way possible. As a preliminary step, a survey was made to ascertain how many acres in the Territory are devoted to banana growing. Approximately 262 acres are under cultivation with 800 plants to the acre. Each plant normally produces one bunch annually. The investigations further showed that there are hundreds of other acres which could be made to yield an abundant crop of bananas annually, since these lands are not used or are not suitable for the growing of either sugar cane or pineapples.

The station selected two new locations for the planting of a number of varieties which are to be grown under different conditions so that results may be carefully studied and records made of the tests. One location consists of 1½ acres in a sheltered valley at the Tantalus substation. This area is largely terraced land that was covered with various kinds of trees, including coffee, rubber, tea, and seedling avocados, all of which had passed their usefulness. Large holes were made 8 feet apart on the terraces and as fast as new offshoots could be obtained they were planted in them. Much effort has been put

forth to collect as many different varieties of banana offshoots as possible in order that they may be studied, and the rarer ones have been kept for further propagation. These bananas are being grown without irrigation, but the location is such that it is thought that the varieties will need only the natural rainfall for growth.

Apparently, some of the varieties that were formerly grown in these islands have disappeared. This is true particularly of the native varieties, the use of which depended largely upon certain characters of the fruit. There were probably about 30 such varieties of bananas in the Hawaiian Islands, but it is now difficult to secure offshoots of half that number.

While it is impossible to provide offshoots of different varieties to growers, it is hoped that distribution can soon be made to interested persons who are cooperating with the station in its endeavors to develop certain varieties for special use.

The second location is at the central station where a small planting of different varieties is being made. Irrigation is supplied this plat when necessary.

The bananas growing in the experimental fields are all varieties of *Musa sapientium*, except the Chinese banana, which is a variety of *M. cavendishii*.

PAPAYAS.

The papaya is rapidly becoming the recognized standard breakfast fruit of Hawaii, and demands for it are increasing as the population of the island increases. This popularity is due to its delicious and wholesome flavor and appetizing appearance. The demand for this fruit is also increasing on the mainland where there is a growing market for Hawaiian fruits. Local companies are utilizing the papaya by the ton, either in the preserved form, or as a jam combined with a by-product of the pineapple. It is also used as a relish and as dehydrated papaya. These uses are leading to the development of a new food industry which promises to become important. Such an industry calls for an abundance of fruit of uniform size and quality, and also for better and easier methods of propagating plants which will produce fruit of such characters. There are almost daily calls at the station for either seeds or plants of the papaya. During the year there were distributed from the propagation house over 5,000 papaya plants, a few of which were given to each person making application. These plants were large enough to be set in the garden. Many packages of papaya seed were also distributed.

The natural habits of the papaya are of such a nature that no true varieties having well-fixed characters can be fully established. This is due to the fact that it is propagated by seeds which are the product

of insect pollination—one of nature's methods of getting variation in plants that are subject to cross-pollination.

Offshoots of papaya trees have been rooted as cuttings at the station and fruit-bearing papaya branches have been grafted on seedling stocks. (Pl. II, Figs. 1 and 2.) These methods have not, however, as yet been sufficiently worked out for use in propagating trees for Hawaiian groves.

Although the papaya is considered a tree that is easy to grow, problems frequently arise in connection with its propagation and complaints of failure often come to the station. These failures may be due to improper soil conditions, water supply, or unsolved fertilizer problems.

During the early part of the year new papaya plantings were planned and field work was begun. At present several varieties of papaya are growing on 2 acres of a new grove at the station. Plants 6 weeks old, which were set in the field on September 15, 1920, began to bloom on November 27, 1920, and now, June 30, 1921, they have fruit reaching maturity. The aim of the experiment is to develop a papaya tree that will conform as nearly as possible to the ideal and can be propagated on a large scale and be grown in all parts of the Hawaiian Islands. The ideal papaya should be one of vigor, having a single, straight, stout trunk tending to remain rather dwarfed. It should begin fruiting early and bear fruit near the ground. (Pl. III, Figs. 1 and 2.) The fruits should grow far enough apart to avoid deformity from crowding. The fruit should be uniform in shape, symmetry, and smoothness. It should ripen evenly, color before softening, and have good keeping qualities. The flesh should be a rich yellow or orange, and the flavor should be sweet, spicy, and highly palatable.

Most of the papaya plantings at the station were renewed this year from seeds of the varieties previously developed here. The old grove has been damaged by the weather and is considered unsatisfactory for further experimental purposes or for seed production.

MANGOES.

The mango work of the year was largely a continuation of that which was begun some years ago. The orchard, which numbers about 30 varieties of budded and seedling trees, was pruned and sprayed, and several hundred seedlings were propagated and set in nursery form for experiments in top-grafting the Pirie and several other choice varieties. Only a few varieties were in fruit in the fall of 1920, and specimens of the Brindabani, Smith-Wootten, and Mullgoa from the orchard were displayed in the station's exhibit

at the Maui County Agricultural Fair from October 21 to 23, inclusive.

Unfortunately the mango orchard is set in shallow soil which is underlain by a rock layer to a depth of from 2 to 3 feet. This has caused the trees to develop their roots near the surface. The orchard can not be cultivated for these reasons and has suffered from drought during the past two summers. The combination of adverse conditions has rendered the orchard susceptible to insect attack.

CITRUS FRUITS.

In the citrus orchard at this station there are many varieties of citrus fruit trees. This orchard is in fairly good condition and nearly all of the trees are productive, notwithstanding the fact that they suffered greatly from drought during the past two summers.

From present indications it is thought that the best citrus fruits for culture in these islands are the Polynesian orange, the sweet shaddock, the Kusaie lime, and the Eureka lemon.

The Polynesian orange, sometimes called the Hawaiian orange or the Kona orange, is evidently one of distinctly Polynesian origin, as it was carried to many of the Pacific Islands by the Polynesian race. In 1792 it was brought into Hawaii from the island of Tahiti by Captain Vancouver. These oranges were the best on the local markets for a great many years, but they were gradually replaced by the highly colored, standard naval oranges from California. The Polynesian orange suffered from the ravages of the Mediterranean fruitfly, which almost caused its destruction. Now the reaction is in effect, and the Polynesian orange is again coming into its own. The fruitfly has been brought under control to a considerable extent by various parasites that have been introduced into the islands. The station will encourage the culture of this orange, which has had its good qualities by a long period of existence in a strictly tropical climate.

The station is also encouraging the culture and use of the Kusaie lime, which has been a popular fruit since its introduction in 1885 from the island of Kusaie in Micronesia (Pl. IV, Fig. 1). This fruit is a large, yellow lime, has few seeds, is smooth, and of excellent flavor. The trees reproduce fairly true to parent from seeds, are resistant to adverse conditions, and are prolific bearers, producing during almost the whole of the year.

The horticultural division has been fortunate in obtaining budwood from a sweet shaddock tree which is a prolific bearer of fruit having a very appetizing flavor. Bud selections are being made of the very best individuals of the three kinds of citrus mentioned above. These will be budded into sour orange, rough lemon, and pomelo

FIG. 1.—PAPAYA TREE, 17 MONTHS OLD. RIDGED TYPE OF FRUIT.

FIG. 2.—PAPAYA TREE, 2 YEARS OLD. SMOOTH TYPE OF FRUIT.

FIG. 1.—KUSAIE LIMES OF EXCELLENT QUALITY. STATION GROUNDS.

FIG. 2.—BLACK MULBERRY. ABUNDANT FRUIT FOR SEVERAL MONTHS IN EACH YEAR.

seedling stock, all of which have made vigorous growth in these islands. It is hoped that the three kinds of citrus can be established with standard qualities and that 2,000 trees of each kind can be propagated by the station for early distribution throughout the Territory (Pl. V, Fig. 1).

GRAPES.

During the year the Hawaii station started a new experimental vineyard with varieties of grapes from various parts of the world to determine their adaptability to Hawaiian climatic and soil conditions. The introduced varieties contain characters which it is thought will improve the grape industry in this Territory. The table and currant varieties received include the White and Black Corinthian, Isabella, Concord, Tropical American, Muscat, Thompson's Seedless, and Almeria.

Grape investigations were first undertaken by the station in 1902, when 50 varieties were introduced into Hawaii. Four years later a cooperative experiment was started on the island of Maui, where 177 varieties, mostly of the wine-grape type, were planted. No definite results were recorded of this planting. Among the first varieties introduced was the Isabella grape, which has been found best adapted to island conditions. During the past few years the station has been carrying on cooperative experimental plantings with private growers to improve the quality and yield of the fruit of the Isabella variety. This work has included methods of trellising, pruning, and the use of fertilizers. From one of these cooperative experiments propagating wood was obtained for starting the Isabella vines being used in the present experiment.

The station vineyard contains many vines of the Isabella grape. This variety seems to thrive in Hawaii, and the fruit can be found in the local markets during almost any month of the year. It is a variety that most amateur gardeners succeed in growing. In November, 1920, about 1,800 cuttings of this variety were rooted in sand and grown in pots to the proper size for planting in the open. All plants not used for the experiment were distributed later to those desiring them for their home gardens.

Two varieties of Corinthian grapes are being tried to determine the possibility of producing dried currants from them. Climatic conditions in certain areas of these islands are apparently suitable for the culture of these currant grapes. Their good characters have been well established by hundreds of years of cultivation in the mild climate of the Grecian Islands, and their culture for exportation in the dried form has long been a leading occupation of many people there. It is hoped that they can be successfully grown in Hawaii.

Muscat, a variety commonly found in California, where it was introduced, was selected for its fine qualities as a fresh fruit and for making raisins, but more especially for its distinctively peculiar flavor, which it is hoped will be transmitted in crossing. It is thought that a locality can be found in Hawaii where conditions will be suitable for the culture of this variety of grape. Thompson's Seedless is remarkable for its good table qualities. It develops well under irrigation in hot, dry localities. Almeria has remarkable keeping qualities and can be used to develop crosses for local culture. The old, reliable Concord has been grown in Hawaii to some extent, and while its fruit is somewhat like that of the Isabella, it has a more desirable flavor than that variety.

Plants of a tropical variety of grape, *Vitis tiliæfolia* (S. P. I. No. 44060), were sent to the station during the year by the Bureau of Plant Industry, United States Department of Agriculture, for crossing with other varieties in the hope of obtaining a hybrid that will be adapted to island conditions.

The objects of conducting experiments with grapes are (1) to determine the most desirable varieties for Hawaiian conditions; (2) to combine by hybridization characters that will give desirable varieties; (3) to combat the Japanese beetle (*Adoretus umbrosus*), which is a very destructive pest of foliage in certain localities; and (4) to determine the best methods of trellising, pruning, and of using fertilizers.

NUTS.

The nut investigations of the year were carried on principally with three species—the Macadamia, or Queensland, nut (*Macadamia ternifolia*), the pistachio nut (*Pistacia vera*), and the coconut (*Cocos nucifera*).

MACADAMIA.

The station has given considerable attention to the propagation of the Macadamia nut. This nut has grown rapidly in public favor since the trees of an early introduction came into bearing. The trees begin to bear at about 7 years of age, producing a crop for more than half the year, and the nuts are of very desirable quality (Pl. I, Fig. 2). The tree is also highly ornamental. Many young trees have been propagated during recent years from the nuts of a few large trees which are growing at the Tantalus substation. The greater number of these have been distributed throughout the islands, and the others have been set in grove form on the station grounds. Seedlings from several different varieties form a part of this collection, and it is hoped that improved types can eventually be selected from them.

The most desired change sought is a variety having a thin shell. Experiments in budding and grafting the Macadamia nut tree are also in progress. The Macadamia nut, described in a former report[5] of this station, is very desirable for growing in tropical and semitropical countries. It is highly nutritious, contains about 66 per cent fat, and has a pleasing flavor.

PISTACHIO.

The pistachio nut, which is being grown with great success in California and sold on the market for a good price, is popular on account of its rich flavor. It is also valuable for the green color it imparts when used in confections. The station obtained some budded trees through the Bureau of Plant Industry, United States Department of Agriculture, and also several pounds of the seeds of the hardy Chinese variety (*Pistacia chinensis*) for hardy stock, on which to bud the choice species of commerce (*P. vera*). A large number of these seedlings have been developed and will soon be ready for budding.

COCONUT.

During the year several tests were made with coconuts to determine the quickest and best way to secure germination. The nuts were buried in a pit of rice hulls in one test, and in a pit of black volcanic sand in a second test. Those which were buried in rice hulls required less time for germination than did the nuts that were buried in sand. Nuts having a small portion of the outer hull cut off at the base and planted with cut ends up germinated best of all. This method enables the small shoot to make straight growth without being retarded. The experiments showed that the coconuts germinate best when they contain the maximum amount of coconut milk. A number of nuts in which the coconut milk had dried failed to germinate when planted. Nuts in good, fresh condition, when set in rice hulls to a depth of 1 foot and kept well moistened, germinated and sent up shoots a foot high in three months. Nuts will germinate in black volcanic sand, but they dry out quickly, similar to the way they do in common soil.

LEGUMINOUS FRUIT TREES.

The station is giving some attention to the growing of four leguminous fruit trees in the hope of increasing their usefulness. The trees are the algaroba, the carob, the guama, and the tamarind, the fruits of which have only little true horticultural value in Hawaii. The algaroba and the carob are the most valuable of the four, owing to their use as feed for live stock. The guama tree was introduced

[5] Hawaii Sta. Rpt. 1919, p. 17.

mainly for its use as a shade tree in coffee growing. The tamarind is an introduced tree that is used principally as a shade tree in Hawaii. It has many uses in other tropical countries.

ALGAROBA (*Prosopis* spp.).

The horticultural division has from time to time received seeds of different species of Prosopis from various parts of the world. These seeds have been germinated and the plants placed in the field for trial. The local algaroba is a most valuable tree and has been fully discussed in a previous publication of this station.[6]

CAROB (*Ceratonia siliqua*).

The carob tree, the fruit of which is known as St. John's bread, is a leguminous tree which is grown extensively in the Mediterranean region for the large nutritious beans it produces. It was introduced into these islands at least 20 years ago, but is only occasionally found now. A new supply of the seed was obtained from California and planted during the year. It germinated well, and a number of trees were distributed to various parts of the Territory. The tree is ornamental, and the beans have a high food value when they are ground into meal for live stock. Many Europeans eat the sweet pulp which fills the pods surrounding the seeds. The carob tree will likely be a valuable acquisition to Hawaii when it is more extensively grown.

GUAMA (*Inga laurina*).

The guama tree is a tropical, leguminous species which is used to shade coffee trees. It is somewhat ornamental and produces one or two crops annually of bean-like seeds, the pods of which are large and plump. The seeds within the pods are surrounded by a mass of cottony-like pulp which is saturated with an edible sirup having a flavor like honey. The guama tree is not a great contestant for the available plant food in the soil. Guama trees are being distributed by the station.

TAMARIND (*Tamarindus indica*).

The tamarind tree was introduced into the Hawaiian Islands early in the nineteenth century, and while it is found growing in various parts of Hawaii, its many uses have not been developed here. The tamarind is a native of the Tropics of the Eastern Hemisphere. It is a medium-sized tree, having graceful acacialike foliage and hard, light-colored wood, which is used for making furniture. The tree

[6] Hawaii Press Bul. No. 26.

bears annual crops of fruit, the pods of which are plump, from 3 to 6 inches long, and filled with a pleasant acidlike pulp surrounding the seeds. This pulp is used for several purposes, but principally for making a cooling beverage. The station plans to extend the cultivation of this tree in the hope of bringing it into more general use.

MISCELLANEOUS FRUIT INVESTIGATIONS.

A study is now being made of certain miscellaneous fruits to determine their value, methods of propagation, and culture in Hawaii. It is thought that many of them will be brought into much more general culture when their real qualities and requirements are understood. The fruits include the star apple, breadfruit, black sapote, black mulberry, litchi, hybrid tomatoes, roselle, poha, and the annonas.

STAR APPLE (*Chrysosphyllum cainito*).

A number of star-apple trees have been propagated from seeds which were obtained from fruit trees growing on the station grounds. These young trees were soon distributed to many persons who are willing to try to grow them.

BREADFRUIT (*Artocarpus incisa*).

The breadfruit tree, the fruit of which was once extensively used for food by the Hawaiians, is now not generally grown. It is thought that its disuse is largely due to the difficulty with which the tree is propagated, and probably to the flavor of the fruit, for which a liking has to be acquired by many people. At present much interest is being manifested in the growing of the breadfruit tree. The fruit is seedless and the trees are usually propagated from root shoots which occasionally spring from surface roots of the parent tree. Very few root shoots could be obtained in the early part of the year. Surface roots were taken from trees which were known to have fruit of good quality. These roots, varying from one-half to 2½ inches in diameter, were made into cuttings about 1 foot in length, and the ends were smoothed with a sharp knife. These were placed in boxes of sea sand, a portion being set upright with about only an inch exposed and a portion being placed obliquely and at the same depth. A third planting was made by laying the cuttings horizontally several inches below the surface. All cuttings were kept moist and in a warm place. After about five months it was found that those laid horizontally below the surface had in part developed shoots and roots and were ready to be transplanted into pots. The cuttings which were set upright are still alive, but at this date (June 30, 1921), seven

months after planting, they continue to show no sign of growth. The test will be continued until it is determined by what method root cuttings of the breadfruit tree can best be developed into plants.

BLACK SAPOTE (*Diospyros ebenaster*).

The black sapote, which is botanically related to the true persimmon, is the only representative of the genus Diospyros that was experimented with by the experiment station during the year. A few plants were germinated from seed which was obtained in these islands. Some were set in the station grounds, and the others were distributed. It is planned to make a further study of this peculiar fruit.

BLACK MULBERRY (*Morus nigra*).

A number of black mulberry trees have been growing at the station for several years. Many cuttings have been taken from these for rooting and distributing. Piece-root grafts were made, 90 per cent of which grew, and these have been distributed. The trees fruited for a period of about five months during the year. (Pl. IV, Fig. 2).

ANNONAS (*Annona* spp.).

The annona group includes a number of tropical fruit-producing plants of widely differing specific characters. Among them are many very excellent tropical fruits. The soursop (*Annona muricata*) and the common custard apple (*A. reticulata*) have been in cultivation for some years and have fruited this season. Another planting of different kinds was put out this year at the Tantalus substation, where it is believed that the 1,000-foot elevation will favor its growth. The following species are under test at the station: Cherimoya (*A. cherimola*), the ilama (*A. diversifolia*), soursop (*A. muricata*), the custard apple (*A. reticulata*), sweetsop (*A. squamosa*), and *A. atemoya*, supposed progeny of a cross between the cherimoya and the sweetsop.

LITCHI (*Nephelium litchi*).

The litchi is a very interesting and promising fruit, but it is rather difficult to grow successfully. The closely related species, the longan (*N. longana*), is being grown as a stock for the true litchi. The following varieties of the litchi (*N. litchi*) are under test at the station: Haak Ip, San Hing Heung Lai, T'in Naam, Saam Uet Hung, Waai Chi, Kwei Mei, and Longan. These varieties were obtained from China, the greater number of them being sent by the Canton Christian College. There is also an unidentified variety of *N. litchi* under test at the station.

HYBRID TOMATOES.

The work of developing hybrid tomatoes, resistant to the Mediterranean fruitfly, was continued during the year. Of the two types of hybrid tomatoes, the round and the oblong, the round type has been found the more satisfactory, and tomatoes approaching the original Earliana in size have been developed (Pl. V, Fig. 2). The demand for these tomatoes was again very gratifying and many packages of seeds and seedling plants were distributed. A specially promising strain of this hybrid was recently turned over to this division by the agronomy division, which was temporarily working with the crop.

ROSELLE (*Hibiscus sabdariffa*).

The roselle has been under test at this station for a number of years. The two varieties giving the most satisfaction are the Victor and the Rico, the latter of which is probably the better for Hawaiian conditions.

The roselle, being an annual, is propagated from seeds. A number of plants were distributed in season during the year. The roselle makes rapid growth, the seeds which are sown early in March, resulting in plants that are ready for transplanting to to the field by May, and the fruit being obtained in November and December. Considerable interest is being taken in the growing of this useful fruit for the making of jams, jellies, etc.

POHA (*Physalis* spp.).

The poha or Cape gooseberry (*Physalis peruviana*), also known as husk tomato or ground cherry, has been growing in Hawaii for many years. It is an introduced plant, but escaped from cultivation and is found growing wild at elevations of from 1,000 to 4,000 feet. The fruit is made into jams, jellies, used in pies, and is a favorite with many people.

Experiments with several kinds of pohalike fruits or husk tomatoes, including the purple giant hybrid, have been in progress, but all fruits produced to date have been found to be far inferior to the fruit of the wild poha. (*P. peruviana*). The experiment, however, will be continued next year with some of the varieties.

DISTRIBUTION OF SEEDS AND PLANTS.

The station has, by its frequent distribution of seeds and propagating materials to interested persons and institutions, been instrumental in extending the growing of improved varieties to all parts of the Territory. These distributions have created a general interest in new

and improved economic plants, brought before the public the plants and shrubs that are useful as well as ornamental, and have resulted in the station receiving much valuable information concerning the possibilities of the plants' success in the particular localities where they were tried.

It is not the function of the station to send out seeds and plants of varieties that can be easily obtained from dealers. Seeds and extra plants that are not needed in the station experiments are distributed at regular hours, semiweekly, throughout the year. Distribution during the year included 125 mulberry trees (grafted), 292 watermelon plants, 5,293 papaya plants, 880 roselle plants, 4,532 tomato plants, 307 mango seedling trees, 12 fig trees, 432 Macadamia nut trees, 274 Kusaie limes, 83 star-apple trees, 117 guama trees, 145 carob trees, 64 granadilla plants, 1,645 hibiscus cuttings, 24 Pirie mango budwood slips, 32 panax cuttings, 32 croton cuttings, 6,234 poha plants, 150 Surinam cherry trees, and 793 grapevines, together with 173 packages of improved papaya seeds, and 53 packages of fly resistant hybrid tomato seeds.

SPRAYING EXPERIMENTS.

Insect pests were unusually troublesome in most parts of the Territory during the past year, owing to the very dry summer. The red spider and a troublesome mite were readily held in check by sulphur sprays which were applied to the affected citrus trees, mango trees, poha plants, etc. In the citrus and mango orchards of the station a spray composed of 50 gallons of water into which $1\frac{3}{4}$ pounds of whale-oil soap and 10 ounces of nicotin sulphate had been dissolved was successfully used. This spray was applied thoroughly with a spray pump as soon as insect attacks were discovered, and the application was repeated about every 10 days until three or four applications had been made.

The common mealybug attacked the maturing fruit of the late mangoes, but was easily brought under control by applying an oil spray made of 1 gallon of San-U-Zay oil and 30 gallons of water.

The mango weevil, which destroys the kernel of the seed of the mango, was very troublesome in some localities during the mango-fruiting season. All fallen mangoes were picked up and burned. This method was found very effective in the past.

The green caterpillar (*Plusia chalcites*), a foliage-eating insect which has been very destructive to many kinds of foliage, appeared in the spring of 1921 in various parts of the Territory. The remedy used for this pest was a spray composed of one-half ounce of arsenate of lead (paste form) combined with a gallon of water. This spray was also effective in reducing the attacks of the Japanese beetle.

FIG. 1.—GROWING CITRUS STOCK ON WHICH TO GRAFT SWEET SHADDOCK AND HAWAIIAN ORANGES.

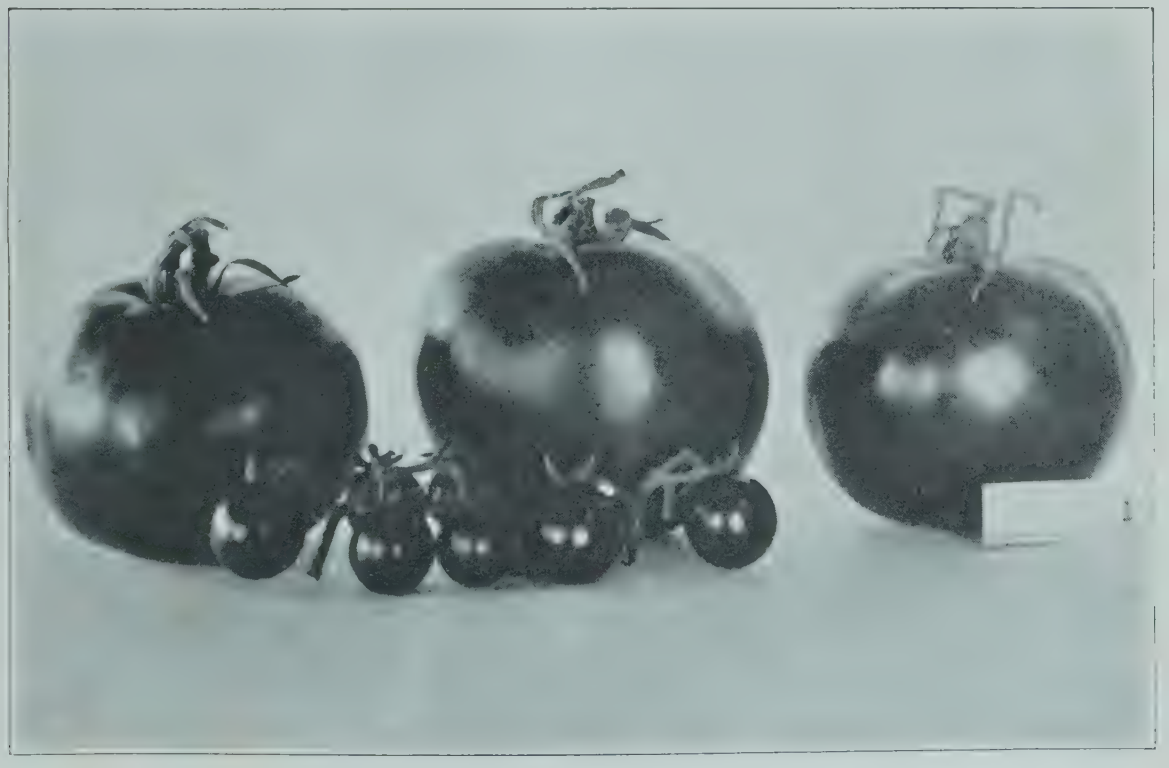

FIG. 2.—HAWAII HYBRID TOMATO. RESULT OF CROSSING EARLIANA WITH POLLEN OF SMALL WILD VARIETY, FRUIT OF WHICH IS SHOWN IN FOREGROUND.

The Mediterranean fruitfly has done much damage in the past to citrus fruits and tomatoes, as well as to other fruits, but destruction has been considerably reduced, apparently by parasitic enemies which have been introduced into Hawaii.

SPECIAL PROPAGATION INVESTIGATIONS.

One of the greatest problems of the plant propagator is how to grow successfully certain plants by methods other than that of planting seeds. The most natural method of propagating plants seems to be by seed, but seed, often the result of cross-fertilization, produces variation. By this method many kinds, or variations of kind, of plants are produced, some of which may show improvement over the parent plant. Many plants reproduce themselves asexually: that is, individuals of the same kind spring up from rooted runners, layers, or separated pieces. Man has extended this asexual process by budding, grafting, and inarching trees and plants, and by planting cuttings. By means of some one of these methods there are now propagated many plants which formerly grew from seed alone. The object of asexual propagation is to avoid variation, and a good variety thus obtained can be retained and handed down through many so-called generations of individuals. There are many plants, however, which do not reproduce easily by these methods and many that have not as yet been so propagated. Carefully worked out methods, however, occasionally show the way in which plants that have never been reproduced asexually may be so produced, and how those which have been so propagated with difficulty may be propagated easily. For example, avocados, mangoes, Bougainvilleas, and others were formerly difficult to root from cuttings or to grow from buds or grafts. Improved methods employed under certain conditions have met with success, and such plants are now considered comparatively easy to propagate.

The station has endeavored to extend into large plantings good varietal characters in the litchi and the papaya, but no methods of asexual propagation have as yet been developed on a practical scale in Hawaii.

The horticultural division is starting an experiment in propagation by means of a "sweat box," which was designed by the Office of Foreign Seed and Plant Introduction, Bureau of Plant Industry, United States Department of Agriculture. This box consists of a strong framework of redwood with sides, ends, and top filled in with double-strength panes of glass. The outside of the box measures 29 inches in width, 32 inches in height, and 42 inches in length. A galvanized-iron pan, which is 2 inches deep and large enough to fit

fairly snugly inside, is supported at about 8 inches above the bottom. On top of the pan are stiff cross-braces of galvanized iron. These hold up galvanized-wire netting of one-half inch mesh, which supports a layer of spaghnum moss over the surface to 2 inches in depth. A high uniform temperature is maintained in the pan by a small electric heater which is placed directly under it, and the water is driven off slowly, causing considerable humidity in the box. The cuttings are placed in some suitable medium, varying in the different experiments, and rest upon the moist spaghnum moss.

REPORT OF THE AGRONOMY DIVISION.

By H. L. Chung.

INTRODUCTION.

The agronomy division again devoted its energies to the production and improvement of food crops for man and forage crops for animals, and to the distribution of propagating material of improved crops. Many activities of a cooperative, demonstrative, and advisory nature were undertaken during the year, including the rejuvenation of old alfalfa fields, the selection of grasses that are best adapted to particular localities, the making of plans for diversified farming, and the solution of problems connected with the poultry industry.

ROOT CROPS.

CASSAVA.

The work with cassava for the year was confined to the propagation of all varieties now growing in the agronomy field in connection with a varietal test. It has been found impossible to grow a satisfactory crop of cassava on the heavy type of soil assigned to it at the station unless the land is given an undue amount of cultivation. For this reason the agronomy division will henceforth grow this root crop principally in cooperation with persons who are interested in it and who have available labor and land that is suitable for the growing of cassava.

EDIBLE CANNA.

During the year the edible canna investigations constituted one of the main subprojects of the division. There has been a great difference of opinion as to the time edible canna corms should be harvested to secure the maximum amount of starch. To determine this a large area was planted in edible canna that was harvested each month beginning with the fourth month after growth. The corms were

washed and dried, the starch was extracted from them, and the quantity of water, fiber, and starch was determined. This investigation was carried on in cooperation with the chemical division of the station. Samples of the corms which were harvested each month were submitted to the chemist for analysis.

SWEET POTATOES.

Sweet-potato investigations were confined largely to two cooperative varietal tests with two ranchers having soils of a similar nature but located about 46 miles apart. In addition, a plat in the agronomy field was planted with several promising varieties which were to be used as propagating material for general distribution.

The first cooperative sweet-potato variety test was carried out on the Kahuku ranch, at Kahuku, Oahu. This land, about 1 acre in size, has very sandy soil and is only a short distance from the ocean. Seven varieties of sweet potatoes were planted 2 feet apart in rows that were spaced 4 feet apart. Every vine made luxuriant growth as the result of the field having been kept sufficiently moist by a modified Skinner system of irrigation. After six months' growth the sweet-potato crop was harvested. About a dozen plants only had developed normal sweet potatoes. The others had well developed, but only slightly enlarged, roots radiating in all directions. The cause of this nonproductiveness was probably due to the new soil condition to which the plants were subjected. It was suggested that the above sweet-potato field be grazed by cattle and later sowed to Australian saltbush (*Atriplex semibaccata.*)

The second sweet-potato experiment was conducted in cooperation with the Kuliouou ranch, island of Oahu. The soil conditions and the results obtained were similar to those of the Kahuku field. Eight varieties of sweet potatoes were planted on March 23, 1920, on half an acre of land on which watermelons had previously been grown. The planting was made in rows 4 feet apart, and the plants were spaced 2 feet apart in the row. Owing to the meager rainfall and the lack of irrigation, the stand was rather poor. The best stand was made by station variety No. 111, of which 60 per cent of the cuttings were established. The poorest stand was made by station variety No. 58, of which only 20 per cent of the cuttings grew. The crop was harvested on September 22, 1920, when each variety bore a few tubers only. Practically all of the vines showed abnormal growth and a decided absence of chlorophyll, the leaves being yellowish to light cream in color. An appreciable amount of salt was detected when the tubers were tested by tasting. Samples were brought to the laboratory for determination of the salt content. Potatoes that grew nearest to the seashore had a slightly higher salt content

than those that grew in other parts of the field. The results of the analysis of the sweet potatoes for their salt content is given in the following table:

Salt content of sweet potatoes produced at various distances from the seashore.

Hawaii station number.	Location of vines.	Water in fresh potato.	Sodium chlorid.	
			In fresh potato.	In oven-dried potato.
		Per cent.	*Per cent.*	*Per cent.*
56	About 100 feet from seashore	73.9	0.594	2.27
56	Middle of the field	70.3	.580	1.95
56	About 335 feet from seashore	69.3	.666	2.18
111	About 100 feet from seashore	78.3	.571	2.63
111	Middle of the field	71.2	.703	2.44
111	About 335 feet from seashore	70.0	.694	2.31
3874	About 100 feet from seashore	74.7	.726	2.37
3871	.....do	77.2	.483	2.12

IRISH POTATO.

Periodic tests were made with the Hamakua Hybrid potato, a variety which had its origin on the island of Hawaii, and which seems to be blight resistant. All tests have revealed the fact that a fairly large crop of merchantable tubers can be produced from stocks that are obtained from the place of their origin, even when no spray is used. Succeeding generations of this variety, however, when grown on the island of Oahu, do not seem to retain their blight-resistant characters. An attempt is being made to develop by selection a strain of this potato which will be blight resistant under all conditions.

TARO.

The taro investigations, especially the variety and fertilizer experiments, were unavoidably delayed by the scarcity of labor for such work and by a rainstorm which partly destroyed the taro dikes. The damaged fields have been repaired and fertilizers have been applied. The harvesting period will begin about November 1, 1921.

The taro crop investigations are considered important and every effort will be made to carry on the work thoroughly during the coming year and thereafter to increase the yield by varietal selection and fertilizing. That there is need of special attention being given to this root crop in Hawaii is evident. The total taro acreage under cultivation by individual native Hawaiians is rapidly diminishing. The taro lands are being abandoned, allowed to lie fallow, or sold for home sites, and as a result only a few people now own taro patches. This has given rise to a deplorable situation, since the few people who own taro lands have absolute control of the price of taro and poi, its product.

CORN.

The corn investigations were confined largely to breeding and selection work. The yellow strain of Guam corn,[7] which this station has been striving to establish, occupied 1 acre at the station and 10 acres elsewhere on the island of Oahu during the year. The work included stabilizing the strain as to color and type of kernels, and increasing the length of the ear by intensive selection. Long and well-filled ears having all yellow kernels and conforming to the characteristics of the original white variety were selected direct from the field and taken to the laboratory for reselection and recording. They were then planted in the field for further selection work.

At the Love ranch, a short distance from Honolulu, about 6 acres were planted in the yellow Guam corn in January, 1921. Matured ears 9½ inches long were commonly found in the field. Such ears were selected for future planting.

A comparative test was made during the year to determine the yield of four varieties of corn for green fodder. The results are given in the following table:

Yield of green fodder from four varieties of corn.[1]

Variety.	Height of stalks.		Yield of fodder per plat.[2]	Calculated yield per acre.
	Maximum.	Average.		
	Feet.	*Feet.*	*Pounds.*	*Tons.*
Guam (white)	9.5	8.5	2,440.0	26.7
Guam (yellow)	9.0	8.0	2,187.5	25.8
Cuban Red	10.0	8.5	2,337.5	27.5
Cuban Red×Guam	10.0	8.5	2,640.0	31.0

[1] Cut 60 days after planting.
[2] The area of each plat was 1,840 square feet.

In addition to the work with the Guam variety, tests were made with a number of varieties which were received from different sources during the year. The sweet varieties (station Nos. 1398, 1399, and 1400), which were donated by Mrs. Shorely, a visiting tourist from New York, failed to develop normally, owing to the ravages of the corn-leaf hopper (*Peregrinis maidis*) and difference of climatic conditions. E. M. Ehrhorn, chief inspector of plants of Hawaii, also donated three varieties (station Nos. 1427, 1428, and 1429) which he obtained from Bolivia. The variety Cuzco (No. 1427) belongs to the *Zea amylacea* type, the kernels being large and soft, and measuring thirteen-sixteenths of an inch long by three-fourths of an inch wide. The other two varieties were members of the flint type. These three varieties were planted and grew to a height of about 10 inches.

[7] Hawaii Sta. Rpt. 1919, p. 44.

Then they gradually withered and died, although no corn-leaf hoppers were to be found on the stalks.

R. P. Bainbridge, of New York, who also visited the station during the year, and who includes sweet corn among his garden hobbies, donated to the station three varieties, Pocahontas Early, Henderson Sweet, and Golden Bantam, which have made remarkable growth. This is the first time that a sweet variety has been grown at the station with any reasonable degree of success. Seeds will be selected from these varieties for future plantings.

NONLEGUMINOUS FORAGE CROPS.

NAPIER AND MERKER GRASSES.

During the year propagating material of Napier or elephant grass (*Pennisetum purpureum*) and Merker grass (*P. merkeri*) was distributed in large amounts to dairymen and to poultrymen throughout the Territory. The station distributed 28,000 more cuttings of these two grasses this year than in 1920.

In connection with the propagation of these two grasses, a study was made of their morphology, habits of growth, and possibilities when they are subjected to various conditions.

UBA CANE.

Uba, or Japanese, cane, which has been growing continuously on the same ground on which it was planted July 17, 1915, bloomed for the first time on December 12, 1920, after its seventh cutting. Five stalks growing in the northwest corner of the field bloomed normally, while 23 other stalks from the same location bore diseased and abnormal tassels. These diseased floral parts developed to a certain stage and then began to decay from within, the decay starting apparently at the floral axis. During the year 4,500 cuttings of Uba cane were distributed.

LEGUMINOUS FORAGE CROPS.

ALFALFA.

A demonstration plat containing different varieties and strains of alfalfa has been started in the agronomy division. In another field a plat of the Peruvian variety was maintained during the year to furnish sufficient seed for distribution in small amounts. In addition to the distribution of the alfalfa seed, 150 pounds of soil for inoculation experiments was sent out in lots varying from a few ounces to 50 pounds.

COWPEAS.

Twenty-one varieties of cowpeas, which were received from the Bureau of Plant Industry, United States Department of Agriculture, were planted on February 3, 1921, between rows of pineapples, which were spaced 4 feet apart. These varieties were grown in a comparative test with varieties that have been growing at the station for some years, the purpose being to determine their relative merits for use as green manure. The following data were obtained when the plants had made two months' growth.

Forage yield of cowpea varieties grown in comparative test.

Station No.	Variety.	Yield of green forage per plat.	Calculated yield per plat.	Station No.	Variety.	Yield of green forage per plat.	Calculated yield per acre.
		Lbs.	*Tons.*			*Lbs.*	*Tons.*
1431	Grout	1.75	0.473	1446	Columbia	6.25	1.69
1432	Large Blackeye	3	.81	1447	Early Buff	9.25	2.5
1433	Couch	7.5	2.03	1448	Early Red	12.5	3.38
1434	Iron	9	2.4	1449	Early Ramshorn	6	1.62
1435	California Blackeye	5	1.3	1450	Sugar Crowder	9.5	2.57
1436	Victor	4	1.08	1451	New Era	18	4.8
1437	Brown Crowder	8	2.16	1412 [1]	Black Select	16.75	4.53
1438	Taylor	5	1.3	872 A	Red Ripper	17.5	4.73
1439	Potomac	12	3.24	1383 A	Station Hybrid	16	4.32
1440	Arlington	2.5	.67	1411	Station Selection	16.5	4.96
1441	Black	6.5	1.76	872 B	Red Ripper	10.5	2.84
1442	Native Blackeye	7	1.89	1383 B	Station Hybrid	14.5	3.78
1443	Extra Early Blackeye	4.5	1.21	1410	Selection No. 1410	11.5	3.11
1444	Buff Catjang	5.75	1.55	877	Taylor	11.5	3.11
1445	Asparagus	8	2.16	1192	Whippoorwill	21	5.6

[1] The last 9 named varieties or selections have been growing at the station for more than 2 years.

KULTHI BEAN.

A 20-foot row of kulthi beans (*Dolichos biflorus*) was planted adjacent to the cowpea plat. The plants were still green after they had produced 2 pounds of matured seeds. The green forage when cut weighed 10 pounds, which production was at the rate of 2.7 tons of green forage per acre. The acre yield of the seeds was 1,089 pounds.

MUNGO BEAN.

A comparative test with the green and yellow mungo beans (*Phaseolus mungo*) showed that the latter variety is far superior to the former in the production of forage. The green variety produced only 77.5 pounds of green matter (1.6 tons per acre) compared with 190 pounds (4.1 tons per acre) produced by the yellow variety. Owing to the fact that the crop was injured by birds, no weight was taken.

LUPINE.

A cultural test was made of a lupine (*Lupinus albus*) that was obtained from the Haiku substation. As a crop for green manure, this variety of lupine yielded at the rate of 4.87 tons per acre, the actual yield being 237.5 pounds from a plat 20 by 50 feet.

KUDZU.

Interest in the kudzu vine (*Pueraria thunbergiana*) has been stimulated by various American and European agricultural periodicals during the past two years, and as a result some of the local people, who are interested in this promising legume, have made numerous requests of the station for propagating material. The plat of kudzu in the agronomy field was too small to supply the necessary cuttings, so seeds were planted in other plats, and later plants were distributed to the public.

Observations were made of the growth of the kudzu plants which were grown from cuttings and seeds to determine the relative merits of each. Accordingly, cuttings made from matured vines were planted in plats containing sandy soil. Kudzu seeds were planted at the same time, and under the same conditions. Four weeks later the resulting plants were set in the field. The transplanting apparently was not detrimental to any of the plants, since they all grew. Later, however, observations showed that the plants which were grown from seeds were making only little progress, while those grown from cuttings made rapid progress and sent forth their long, pubescent vines in all directions. Twelve months after transplanting there were harvested 10 hills of kudzu plants from cuttings and from seeds. Every plant that grew from cuttings bore one or more enlarged roots, while the plants that were grown from seeds had elongated fleshy roots only (Pl. VI, Fig. 1), although the growth of the foliage of the two was about equal.

In addition to the above-mentioned work on kudzu, samples of hay, meal, crude and refined starch, and fiber were made from the kudzu plant for exhibition purposes.

THE YAM BEAN.

The yam bean (*Pachyrrhizus tuberosus*) is a legume that is little known to American or European agriculture. It is cultivated by the farmers of the Orient for its fleshy and edible roots. (Pl. VII, Figs. 1 and 2). Fifty seeds were obtained from a local vegetable grower and planted in field N. No attempt was made to determine the yield of the root crop, because the planting was made primarily to obtain a supply of seeds for sowing a larger area for the purpose of studying the growth, habits, and yield possibilities of the plant.

FIG. 1.—PLANT OF KUDZU 7 MONTHS FROM SEED, SHOWING HEAVY, FLESHY ROOT SYSTEM.

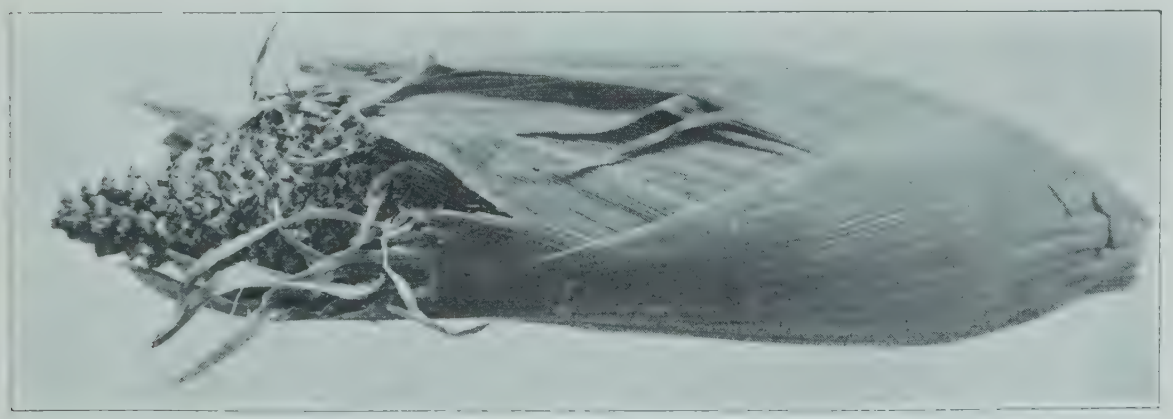

FIG. 2.—EAR OF CORN DAMAGED BY ENGLISH SPARROWS.

FIG. 1.—FOLIAGE, FLOWERS, AND PODS OF YAM BEAN (PACHYRRHIZUS TUBEROSUS)

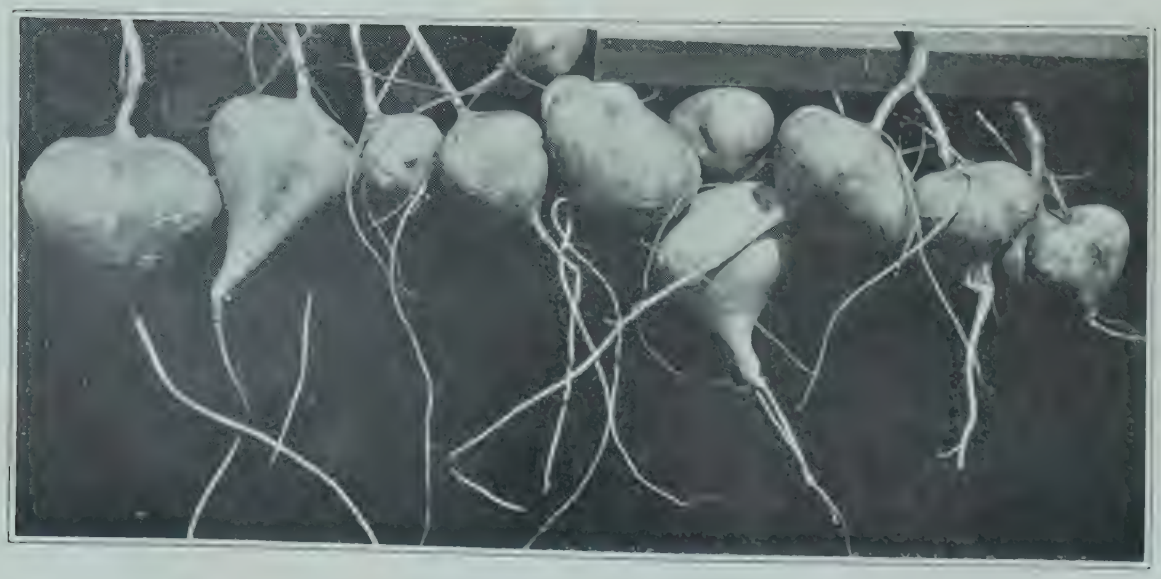

FIG. 2.—ROOTS OF YAM BEAN; EXTENSIVELY GROWN BY ORIENTALS AS A FAVORITE VEGETABLE.

PEANUTS.

No experimental work was undertaken with peanuts during the year. This legume was used extensively, however, for crop rotation, and incidentally to replenish the seed supply for distribution.

MISCELLANEOUS CROPS.

CABBAGE.

A comprehensive fertilizer experiment was begun by the agronomy division to determine the fertilizer that is best suited for three varieties of Chinese cabbage. The planting was made on December 8, 1920, and the fertilizers were applied 20 days later. A rainstorm occurred in January and destroyed the entire experimental planting of cabbage. Between January 1 and 21, 1921, a total of 14.3 inches of rain fell. A second planting was then made with the seeds that were on hand. The result of the test will be reported in the next annual report.

TOMATO.

The agronomist did some tomato-breeding work in a private capacity at his home, using the Cowan hybrids [8] as foundation stock. A continuous selection and breeding experiment with a limited number of plants gave a prolific tomato plant which reproduced itself with fruits larger than the original Cowan cross. The tomatoes show a remarkable degree of resistance to the attacks of the melon fly (*Bactrocera cucurbitæ*) if the large number of ripe and uninjured fruits obtained can be taken as an indication of their fly-resistant character.

Seeds of this particular tomato plant were saved and turned over to the agronomy division on December 1, 1919, so that proper methods of increasing and improving the variety could be followed. A small plat in the agronomy field was planted to this tomato selection, together with a number of standard varieties for crossing. Three hundred successful crosses were secured and the hybridized seeds were turned over to the horticultural division, where the work of improving a fly-resistant variety with large fruits will be continued.

ENEMIES.

BIRDS.

The English sparrow (*Passer domesticus*) was a serious pest of the bean and corn crops at the station during the year. The bean crop, while still in its green stage, was shelled by these birds, and an accurate yield of the seed crop could not therefore be obtained. The ears of corn were damaged by the birds, which removed the green shucks at the tip to gain access to the kernels. After sufficient mois-

[8] Hawaii Sta. Rpt. 1918, p. 19.

ture had gathered about the damaged parts the ears decayed. (Pl. VI, Fig. 2.)

The English sparrow is a very destructive pest to food crops in Hawaii, and unless its rapid reproduction is curbed the growing of beans and similar crops will be greatly handicapped.

The rice birds (*Munia nisoria*) also did considerable damage in the agronomy field. On one-tenth acre planted to three varieties of Chinese cabbage for seed production, these birds have commenced to shell the green seed pods for the matured seed.

INSECT PESTS.

Corn-leaf hoppers (*Peregrinis maidis*) appeared in large numbers as usual in the agronomy field where corn was growing, but their damage was negligible so far as the Cuban Red and Guam varieties were concerned. The other new varieties of corn were severely damaged, however, the entire crop being ruined.

The common cabbage worm (*Pontia rapæ*) damaged the cabbage fields to some extent by devouring the tender leaves. This pest was parasitized by *Frontina archippivora*, which helped to destroy most of the larvæ. Many parasitized individuals were found on the under surface of the cabbage leaves.

The presence in great numbers of weevils (*Bruchus chinensis* and *Calandra oryzæ*) have made it necessary to fumigate the corn and bean seed monthly.

The cane-leaf hopper (*Perkinsiella saccharicida*) was observed on the Uba cane at this station for the first time on December 12, 1920. Only a few of these pests were found, and they soon disappeared. Examination of the cane leaves showed the presence of many eggs. No nymphs, however, have been observed as yet.

POULTRY.

During the World War the citizens of Hawaii were urged by the national and Territorial agencies to produce as much vegetable and animal food as possible. In response many undertook gardening in their back yards, and others combined poultry raising with vegetable gardening. These war-time measures were not abandoned with the cessation of hostilities, and many who had acquired an interest in the work decided to continue it; others were obliged to do so on account of the high price of vegetable and poultry products. Many interested but inexperienced poultry keepers who were successful during the first and second years of their undertaking called on the agronomy division for assistance when their flocks became affected with various kinds of disease. Although the energies of the agronomy division are largely devoted to work with farm crops, a portion of it was given to pressing poultry problems needing solution. In no

instance, however, did the time given to poultry work jeopardize the agronomic work.

Timely illustrated articles dealing with the poultry industry were frequently prepared by the agronomy division for publication in one of the local daily newspapers. The articles conveyed useful information, applicable to Hawaiian conditions, to poultrymen in the Territory.

Caponizing is one phase of the poultry industry in which the local poultrymen are very much interested. The capon is in great demand during the holiday festival season, which is observed by the Chinese in Hawaii, and it sells for $1.25 per pound. At this price, a fowl of the American class weighing 12 pounds will net an exceptionally good return. The local market, however, prefers birds weighing not more than half that weight.

During the year the agronomist's attention was called to two diseases that were affecting the poultry of the island. In one disease the glandular stomach of young fowls became abnormally enlarged as a result of being heavily infested with round worms (*Dispharagus nasutus*). Eighty-eight large and small worms were found in the stomach of one fowl. The cause of the other disease has not as yet been determined. A six-weeks old Black Minorca chick, which was the third victim of this disease, was apparently normal in the morning, but commenced to stagger about noon, and died before night. A post-mortem examination showed no sign of external or internal injury to the body, and the respiratory organs and digestive tract were found to be normal other than for the two cæca, which were filled with coagulated blood.

Although the poultry industry in Hawaii is still in its embryonic stage, it promises to make rapid development, and it is hoped that means will be found to enable it to become established on a profitable basis. The station expects to continue to assist and encourage local poultry and egg production in every way possible. It is hoped that a strain of fowls best adapted for egg production under local conditions can be developed within the next year or two, and that egg-laying contests can be held to stimulate interest in the poultry industry.

REPORT OF THE CHEMICAL DIVISION.

By J. C. Ripperton.

INTRODUCTION.

The major part of the work of the chemical division for the year was devoted to the cooperative experiments which were started dur-

ing the previous year, and to making analyses of soils, fruits, root crops, starch, and starch residues.

COOPERATIVE FERTILIZER EXPERIMENTS.

PINEAPPLES.

The first crop of pineapples in the fertilizer experiments was harvested on June 30, 1921. The whole field had made exceptionally vigorous growth. Half of every plat was given a small supplementary application of fertilizer when the plants were in the flowering stage, at which time they are most inclined to collapse. Wilt is already beginning to appear throughout the fields.

BANANAS.

An unusually severe windstorm uprooted almost the whole banana field before half of this year's crop was harvested. The stalks which had fallen were cut so that the new offsets or suckers would have a better chance to develop. No very pronounced effects of the fertilizer treatment could be observed. The experiment will be continued with the next crop.

UPLAND SUGAR CANE.

During the summer of 1920 the drought was so severe that upland sugar cane made very slow growth. The cane is now making vigorous growth, but it will not be ready for cutting until the autumn of 1921.

FERTILITY-ROTATION EXPERIMENT.

This experiment is planned to provide short rotations for pineapples and sugar cane, and at the same time maintain soil fertility by plowing under pigeon peas as a green-manuring crop. During the year one pigeon-pea crop was harvested and the succeeding crop was plowed under. The plan is to harvest one crop and turn under the next crop each year. The first harvest of pineapples is under way (June 30, 1921). The sugar-cane crop will not be cut until the fall of 1921.

PINEAPPLE-WILT EXPERIMENT.

The pineapple-wilt investigations were abandoned after the first crop of pineapples was harvested, the station deeming it advisable to withdraw from the field because of the extensive experiments that were being undertaken by a local association.

From the standpoint of the "wilt," the experiment gave no positive results. The disease was equally as severe on the treated as on the untreated plats. On plats Nos. 1 and 23 the spray was so concentrated that the tops of all the plants were burned. The wilt has

attacked the new growth with as much vigor as it has the old growth. Pineapple growers agree that chemical sprays are of little or no avail in checking the disease. Where they were used, small increases in weight of fruit and decreases in No. 2 fruit were apparent. Slight gains were made when acid phosphate and ammonium sulphate were applied to the plats. The results of the first harvest are given in the following table:

Results of applying certain disinfectants and fertilizers to the first crop of pineapples affected with wilt.[1]

[Unless otherwise stated, the following concentrations of solutions were used: Copper sulphate, 1–1,000; ammonium sulphate, 1–16; acid phosphate, 1–40; and potassium sulphate, 1–80.]

Number of plat.	Treatment applied to plants.	Number of fruits picked.		Average weight per fruit.
		No. 1.	No. 2.	
				Pounds.
1	Copper sulphate (1–100); tops[2]	22	1	4.20
2	Copper sulphate; tops	214	12	4.53
	Check plat	221	19	4.40
3	Copper sulphate; roots[3]	215	18	4.40
4	Copper sulphate (1–10,000); tops	188	12	4.63
	Check plat	192	16	4.54
5	Ammonium sulphate; tops	180	17	4.51
6	Ammonium sulphate and copper sulphate; tops	179	14	4.43
	Check plat	170	34	4.31
7	Ammonium sulphate; roots	161	7	4.64
8	Ammonium sulphate and copper sulphate; roots	219	14	4.64
	Check plat	183	19	4.37
9	Copper sulphate (1–10,000); tops	161	27	4.16
10	Copper sulphate (1–10,000); roots	172	23	4.52
	Check plat	178	29	4.33
11	Bordeaux mixture (1–1–10); tops	180	17	4.36
12	Bordeaux mixture (1–1–10); roots	183	34	4.21
	Check plat	134	21	4.24
13	Acid phosphate; tops	115	12	4.46
14	Acid phosphate; roots	129	16	4.64
	Check plat	165	16	4.27
15	Acid phosphate and copper sulphate; tops	58	10	4.21
16	Acid phosphate and copper sulphate; roots	133	16	4.38
	Check plat	141	21	4.23
17	Acid phosphate and ammonium sulphate; tops	124	10	4.36
18	Acid phosphate and ammonium sulphate; roots	117	32	4.11
	Check plat	145	24	4.22
19	Acid phosphate, ammonium sulphate, and copper sulphate; tops	156	12	4.57
20	Acid phosphate, ammonium sulphate, and copper sulphate; roots	144	20	4.27
	Check plat	144	28	4.11
21	Acid phosphate, ammonium sulphate, copper sulphate, and potassium sulphate; tops	111	10	4.34
22	Acid phosphate, ammonium sulphate, copper sulphate, and potassium sulphate; roots	152	16	4.56
	Check plat	127	28	4.02
23	Mercuric chlorid (1–4,000); tops			
24	Mercuric chlorid (1–4,000); roots	100	11	4.25
	Check plat	120	40	4.10
25	Potassium permanganate, ferrous sulphate, and sulphuric acid (1–3–10–600); tops	112	17	4.24
26	Potassium permanganate, ferrous sulphate, and sulphuric acid (1–3–10–600); roots	100	17	3.96
	Check plat	48	5	4.21
27	Acid sodium arsenite (1–10,000); tops	10	1	4.10
28	Acid sodium arsenite (1–10,000); roots	70	22	4.08
	Check plat	105	31	4.11
29	Potassium sulphate and magnesium sulphate (1–40); tops	119	41	4.04
30	Potassium sulphate and magnesium sulphate (1–40); roots	105	21	4.19
	Check plat	136	28	4.06

[1] The fertilized plat is a part of a large plantation pineapple field, and on two occasions the plantation laborers inadvertently removed the prime, ripe fruits from each row. It is thought, however, that the results of the remaining fruits are sufficiently reliable for use since approximately equal percentages were taken from each row.

[2] Application to tops was made by spraying 1 pound of solution upon each plant.

[3] Application to roots was made by pouring 1 pound of solution about the base of each plant.

PAPAIN-EXTRACTION EXPERIMENTS.

During the year samples of papain were extracted from papaya fruits and sent to an eastern drug company. The quality was declared to be greatly superior to that on the market. Cheaper and more effective methods of extraction must be developed, however, before the industry will be commercially practicable in Hawaii. A grove of 40 papaya trees has been planted to furnish the necessary papaya fruits for further work in this connection.

HAWAIIAN STARCHES.

Pure samples of starch from the tree fern, sweet potato, cassava, and edible canna have been made. Physical and chemical tests will be made to compare them with the commercial starches that are found on the market. The home demonstration collaborator of the station is preparing recipes for the use of each of the starches. It is hoped that as a result of these investigations with Hawaiian starches the islands will export rather than import this material in the near future.

Samples of starches extracted from the edible canna, sweet potato, cassava, and Irish potato were analyzed at the Haiku substation and found to be of excellent purity. The analyses of the residues, however, indicate a very low percentage of extraction. Analyses were made of the residues of the edible canna, sweet potato, and Irish potato to determine the amount of starch remaining after commercial extraction, and the results were found to be 70.85, 69.5, and 64.95 per cent, respectively. A study is being made of the entire process of extraction to devise methods of getting a more nearly complete recovery of the total starch. The starch-extraction machinery at the station consists of a shredder, a perforated screen through which the starch is washed by water that is played upon the pulp, and settling tanks in which the starch is rewashed. Owing to the relatively small percentages of the constituents other than starch found in root crops, and the large quantities of water used in the extraction and washing of the starch, only traces of protein, fat, and ash remain, and crude fiber is the only impurity found in appreciable amounts. The following table shows the results of extracting starch from some Hawaiian root crops:

Analysis of commercially extracted starches.

Material.	Water.	Crude fiber.	Starch.
	Per cent.	*Per cent.*	*Per cent.*
Edible canna	18.73	0.10	81.2
Sweet potato	15.66	.22	84.3
Cassava	15.91	.28	83.6

TREE-FERN STARCH.

During the year the station started experiments with the tree fern for the production of starch (Pl. VIII, Fig. 1). A company in Hilo is producing tree-fern starch for commercial purposes. The tree fern is found scattered over the windward slopes of nearly every mountain on the islands. It is estimated that there are 400,000 acres of tree-fern forests on the island of Hawaii alone. A very large part of this is within the forest reserve or Government-owned lands, from which it is illegal to cut the tree fern. There is enough privately owned land, however, which can be purchased for building up a starch-producing industry of considerable size.

To manufacture the starch the tree fern is first cut and the outer bark is slabbed off in the forest. The core of the average size fern weighs from 50 to 70 pounds and is nearly pure starch (Pl. VIII, Fig. 2). Pure tree-fern starch is obtained from the core by the same process that starch is manufactured from the potato; that is, by shredding the core, screening to remove the fiber, washing the starch, and finally by drying. It can be used as a substitute for cornstarch or for other purpose. Efforts have been made to demonstrate the possibilities of this food product by means of window displays, commercial-club lunches at which tree-fern dessert is served, and in other ways. Assistance is also being given in studying the details of manufacture. Only 50 per cent of the starch was recovered in the process of starch extraction. The product is an excellent starch and resembles arrowroot in many respects. The following table shows that its purity compares favorably with other starches on the market:

Composition of tree-fern starch compared with that of other commercial starches.

Material.	Water.	Crude fiber.	Starch.[1]
	Per cent.	*Per cent.*	*Per cent.*
Tree-fern starch [2]	17.9	0.09	82.01
Do.[3]	16.43	.14	83.43
Cornstarch	12.78	.12	87.1
Arrowroot	17.14	.06	82.80

[1] Calculated by difference. [2] Received August, 1920. [3] Received January, 1921.

If the tree-fern starch industry is to become a permanent one in Hawaii, some method of replanting the cut-over areas must be adopted. Three experimental plats have been established in the Puna district on the island of Hawaii for the study of the propagation of the tree fern. Cuttings from different parts of the fern have been planted. It is believed that an average of three plants can be obtained from each tree fern that is cut.

The rate of growth of the tree fern is also of fundamental importance. Residents of the district vary in their opinion from 10 to 50

years regarding the length of time the tree fern requires to reach maturity. If the time exceeds 20 years it is hardly likely that there are sufficient available tree ferns on the islands to maintain an industry until the replanted areas can furnish new material. On the other hand, if a tree 8 feet tall can be grown in 15 years, and three successful plantings can be made for every tree fern that is cut, a permanent and increasing supply could be assured. A method of determining the age has been worked out by the station, but its accuracy needs to be tested by actual yearly measurements. It is believed that the tree fern in this district makes an average yearly growth in height of from 6 to 8 inches. It would seem advisable to make the vast tree-fern sections of the islands the main starch producing areas, since they are of very low pasturage value and not adapted to tillage. This is, of course, dependent upon the development of satisfactory methods of reforestation of the cut-over areas so that the mountain slopes would be covered at all times.

PRESERVATION OF HAWAIIAN FRUITS AND VEGETABLES.

The station has succeeded in solving many problems for the local canners. The canning industry, other than pineapple canning, is still small, but it offers an increasing outlet for Hawaiian fruits. Jars of Hawaiian jellies, jams, and preserves, together with canned fruits and vegetables, and recipes for each, are being prepared for Territorial exhibits and for demonstration purposes. An attempt is being made to develop a simple inexpensive apparatus for household use in jelly making.

Experiments on drying Hawaiian fruits have been continued. The purpose of this work is to encourage the industrial development of dehydrated Hawaiian fruits. A small laboratory drier has been installed at the station for the purpose of experimentation and demonstration. It is felt that there is very little need for the home drying of vegetables in Hawaii because they can be had fresh nearly the year around. Considerable interest is being manifested in the commercial drying of bananas, and growers are hoping to find some profitable means of disposing of their cull bananas. The recent marine strike has been instrumental in emphasizing the need of drying as a safeguard against transportation difficulties. Effort is being made to induce some commercial dehydrating company to install an experimental plant with some local company to demonstrate the feasibility of commercially drying Hawaiian products. There is some prospect of success in the commercial drying of vegetables, especially on those remote areas which have been set aside by the Hawaiian Homes Commission Act recently passed by Congress.

FIG. 1.—TREE FERNS USED FOR STARCH PRODUCTION. PLANTED AT GLENWOOD SUBSTATION IN 1913

FIG. 2.—SECTION OF TRUNKS OF TWO VARIETIES OF TREE FERNS. LEFT, HAPU; RIGHT, HAPU III.

EFFECT ON CROPS OF BRACKISH IRRIGATION WATER.

Numerous requests were received concerning the tolerance of local crops to brackish irrigation water. A great deal of the water from wells is drawn from near or below sea level, and consequently tends to become brackish if the well is pumped too hard. No data are at hand regarding the salt limit of most of Hawaii's crops. The maximum concentration for sugar cane, however, is said to be from 40 to 50 grains of sodium chlorid per gallon. Alfalfa and corn have been found growing vigorously with water containing 58 grains per gallon. Some new wells, which were recently dug and which are being used, contain as high as 108 grains of sodium chlorid per gallon. There is evidence of a cumulative effect on some lands where old alfalfa is growing, but where it is impossible to get a new stand. Samples of sweet potatoes when analyzed were found to contain as high as 0.74 per cent (2.94 per cent dry weight) of sodium chlorid and had a distinctly salty taste. It is planned to continue work with pot experiments as well as with field tests to determine the tolerance of certain crops to brackish water and to ascertain the cumulative effect after long-continued use of brackish irrigation water.

REPORT OF THE EXTENSION DIVISION.

By F. G. Krauss.

INTRODUCTION.

In view of the fact that the superintendent of extension presented his resignation to take effect shortly after the close of this fiscal year, the seventh year since he inaugurated the work, a brief review of his work is given herewith.

Agricultural extension work was definitely inaugurated in Hawaii in November, 1914, for the purpose of furnishing the practical farmer with the available agricultural data accumulated by the United States Department of Agriculture, the various State experiment stations, and other agencies. The work was authorized by Congress, which added a fund of $5,000 to the regular appropriation of the Hawaii station. In 1919 this sum was increased to $10,000. Previous to this the extension work was largely supported from funds provided by local subscriptions and appropriations by the Territorial Legislature. The limited funds necessitated close cooperation between the station's specialists and the up-to-date, representative farmer-collaborators who are engaged at a nominal

sum to demonstrate the most approved agricultural practices in their respective communities and in the outlying islands.

Through the efforts of the superintendent of extension the farmer has been given every assistance in the establishment of better markets for crops and in the development of standard grades of products to meet the demands of the best buyers. Farmers' associations have been formed for the benefit of those living in remote agricultural districts, and careful attention has been given to the marketing and utilization of local crops, and to the wisest expenditure of the profits accruing from them. A number of demonstrations have been made in agricultural communities having the greatest need of them. In various localities the work has included efficient systems of rotation of crops that are beneficial to the island; cooperative experiments in dynamiting and in treating soils antiseptically in pineapple culture; forage-crop and pasture-grass experiments; a great number of comparative tests of field crops; leguminous crop demonstrations; the development of diversified agriculture on the islands; the working out of satisfactory methods of storage, grading, and marketing of comparatively new crops; and experiments in tillage, planting, fertilizing, green manuring, and drainage. Various groups of farmers have been shown how to draw up contracts with the pineapple canneries and the sugar mills for the disposal of their products.

Deeming it expedient to establish his headquarters in a center tributary to an agricultural community, the superintendent of extension selected two homestead units of approximately 50 acres each at Haiku, island of Maui, as a substation and demonstration farm. Haiku was selected because it is an important agricultural region and is adjacent to flourishing sugar and pineapple plantations. Two large tracts of land have been opened up there for homesteading by the island government and plantation owners. A meteorological station, including temperature, precipitation, and wind velocity observations, was established at Haiku in January, 1916, in cooperation with the United States Weather Bureau. The vast amount of work done at the Haiku substation and demonstration farm has been beneficial not only to the immediate agricultural center, but to the whole island group.

The extension division has been instrumental in improving the live-stock industry of the island, manufacturing various agricultural products, and in distributing seeds and literature. Lectures have been delivered on timely topics, and numerous articles have been prepared for the press. In addition to organizing the boys' and girls' club work, the station has fostered school-garden contests, and assisted the boy-scout work and the Boys' Working Reserve.

EXTENSION ACTIVITIES OF THE YEAR.

During the year a great deal of the superintendent's time was devoted to advisory work, there being an ever increasing demand for his services in this capacity. This work has necessitated greater need for travel than was the case in former years. Two trips were made from the headquarters at Haiku, Maui, over the islands of Hawaii and Kauai, and one over the island of Molokai. In addition, four trips were made to the island of Oahu. In cooperation with the extension service of the University of Hawaii and the experiment station of the Hawaiian Sugar Planters' Association, a lecture tour was conducted over the islands of Hawaii, Kauai, and Maui, where the superintendent addressed many assemblages of school children, teachers, small farmers, plantation men, and townsfolk in country and city. Well organized lecture tours, especially when they are accompanied by good stereopticon views and moving pictures, give a healthy stimulus to the promotion of a broader and more diversified agriculture.

Other phases of wholesome agricultural propaganda in which the extension division took an active part were the agricultural fairs. The third annual Maui County Agricultural Fair, held from October 21 to 23, inclusive, was very well attended and created so much interest and enthusiasm that it has been decided to extend the work to other localities. The superintendent again acted as chairman of the agronomy section, and the boys' and girls' agricultural club work, which was inaugurated with the first annual Maui County Agricultural Fair, was maintained in a flourishing condition. The extension division has invariably taken advantage of every opportunity to make large and comprehensive exhibits at the county and Territorial fairs.

The school and home garden activities of the Territory, which have grown to formidable proportions, have always received the hearty support of the extension division. Thousands of packets of vegetable seeds, cuttings, and rooted plants, as well as fertilizers and insecticides, have been distributed annually from the extension headquarters at Haiku to further this work. Planting, pruning, and spraying demonstrations, together with numerous lectures, have been given both to teachers and school children, proving beneficial to all concerned. The superintendent has gained much useful information concerning vegetable varieties and their behavior under the varying environments to which they have been subjected in these activities. During the year the superintendent again acted in the capacity of judge of the school gardens of the island of Maui.

The persistent efforts of the station to extend dairying throughout the Territory, especially on the sugar-cane and pineapple planta-

tions where thousands of laborers are employed, have met with gratifying results. During the year the extension division was called upon for advice in the planning and equipping of three large, modern dairies in widely separated parts of the Territory, and assisted in having several fine dairy herds, including some outstanding sires, imported into the island. The results of this introduction should become far reaching as time goes on. The division was also instrumental in establishing the first cooperative bull association in the islands.

The work of the division in encouraging the development of the swine industry has been reported upon in former reports. The extension headquarters at Haiku has distributed about 300 head of registered Berkshire pigs during the past five years, with the result that a high grade of Berkshire swine now predominates in the Territory. A similar work has been done in the development of the poultry industry. A large flock of superior Single Comb White Leghorn chickens has been maintained at the Haiku demonstration farm since its establishment.

Probably the most important and far reaching new and high type of agricultural activity sponsored by the extension division is that of growing and marketing choice, pedigreed farm and field seeds. From a very small beginning of growing and selling superior strains of farm seeds at the Haiku substation and demonstration farm in 1914, there has grown a large demand for corn and leguminous seeds, especially of the pigeon pea. Orders for more than 20 tons of pigeon-pea seed (enough to plant 4,000 acres) at $300 per ton were received by the station and passed to accredited growers for filling during the year. Hawaii has ideal conditions for the production of high-grade tropical farm seed, and no doubt could develop a seed trade that would become one of its leading industries were her seed merchants to advertise throughout the world. The production of high-grade seed is one of the highest types of agriculture.

During the year the station received and answered about 1,000 letters relating to the work of the extension division. It also maintained a weekly agricultural page in one of the leading daily newspapers, the superintendent and other members of the station staff preparing original and timely articles for publication. At the Haiku substation and demonstration farm a circulating agricultural library and reading room was placed at the service of the public. and agricultural periodicals of a popular nature, after serving their purpose at the substation, were distributed to the farmers of the islands. The superintendent had charge of the Federal quarantine for the island of Maui and inspected all bananas and pineapples before they were shipped to the mainland. Complete meteorological records were again kept at the Haiku substation.

COLLABORATORS.

In the absence of the usually established farm bureaus and county-agent systems, of which the islands are in urgent need, the employment of representative farmers as collaborators in their respective districts has been both practical and economical. Much credit is due these coworkers for their untiring efforts to give to their neighbors the most approved agricultural practices and supplies of seeds and plants.

Of more recent development, and one from which far-reaching results are expected, is the cooperative buying and selling agency which is being developed in Hilo by J. E. Gamalielson, who was for a number of years collaborator of the extension division at Kaumana, Hilo, Hawaii. Mr. Gamalielson is manager of the Glenwood Creamery Co., a cooperative organization of dairy farmers which was established in 1913 through the efforts of the Glenwood substation. In addition to the above-mentioned business enterprises Mr. Gamalielson has successfully managed a diversified farm of 95 acres at Kaumana near Hilo, where his principal lines of work have been dairying and poultry raising. The report for his business for the calendar year 1920 is as follows:

On every Monday and Thursday of the year butter to the aggregate of 3,183 pounds was marketed for the cooperative organization known as the Glenwood Creamery Co. This butter consisted of that which was left after the local demand was supplied. The average price paid per pound was 73.56 cents, and the total returns amounted $2,341.41. A charge of $120.16 for the year was made for selling the butter. The balance remaining after the freight charges were paid was returned to the farmers. Practically one day in each month was given to billing, collecting, and remitting.

Considerable attention was given to secretarial duties connected with the Rochdale Cooperative Association (Ltd.), of Hilo. The membership roll of this association contains nearly 500 names, including those of farmers, railroad men, school-teachers, and county employees. The association was formed for the purpose of purchasing and distributing general supplies and for marketing farm produce. The business for the year amounted to $126,015.57. The farm operated by this collaborator showed a satisfactory return for the year, as is evidenced by the following statement.

Financial report of the collaborator at Kaumana for the year ending December 1, 1920.

Expenditures.		Receipts.	
Feed for chickens and cows	$1,971.41	Eggs marketed (dozens) 4,648	$4,683.47
Labor pay roll	1,160.00	Butter marketed (pounds) 1,009	787.11
Light, heat, power	109.70	Cream marketed (quarts) 515	501.85
Telephone rent	49.10	Chickens marketed (number) 321	385.84
Rent for pasture lot	100.00	Vegetables marketed	23.66
Taxes and licenses	220.44	Accrued incoming rent on farm land	516.00
House and fence repairs	222.82	Value of chickens raised	500.00
Auto and machinery repairs	199.85	Calves and hides sold	14.15
Gasoline and oil	149.50	Salaries and fees	420.14
Interest and insurance	29.87		
Allowance for depreciation	500.00	Total income for period	7,832.22
Total	4,712.69	Gain during period	3,119.53

John de C. Jerves, collaborator at Kalaheo, Kaui, has for many years successfully demonstrated that a small homestead, well located and tilled, can be made profitable. Mr. Jerves introduced the well-known Madeira sweet potato, thousands of cuttings of which he has distributed throughout the Territory. The Madeira sweet potato continues to be one of Hawaii's best culinary varieties. It requires from six to eight months to mature and has yielded an average of over 8 tons per acre for many years at the Haiku substation and demonstration farm. Recently Mr. Jerves replaced a grade herd with a foundation herd of Berkshire swine to obtain pedigreed stock for sale purposes. Dry-land taro, corn, Irish potatoes, beans, and forage crops are grown to the limit of his available area. Mr. Jerves's farm probably raises as great a proportion of the products that are essential to the maintenance of the family and live stock as any farm in these islands.

X. L. Helbush has served as collaborator at the Glenwood substation and demonstration farm, and M. A. Dees has held a similar position in connection with the Haleakala substation and demonstration farm. Mrs. Nellie A. Russell has served as collaborator in home demonstration work, and the report of her activities immediately follows.

REPORT OF HOME DEMONSTRATION ACTIVITIES.

By Mrs. N. A. Russell.

Active home demonstration work was commenced on November 1, 1920, and one day a week thereafter was devoted to the various phases of home economics. A fairly complete collection comprising 62 samples of jams, jellies, and pickles from local fruits and vegetables was made up and placed on exhibition. From two to four recipes each were worked out for Natal plums, papayas, roselle limes, oranges, figs, carambola, pineapples, grapes, and tomatoes.

During December, 1920, and January, 1921, 16 recipes were worked out for the utilization of tree-fern starch, a commercially new local product. An exhibit that was placed in the window of one of the leading grocery stores resulted in many inquiries. To further the use of this home product the leading business men's club was provided with dessert made from the starch. Samples of starch, raw and cooked, were also distributed to all the members of the housewives' league.

In February, 1921, a plan was formulated for furthering extension work by having social workers, plantation managers, and women's clubs assemble at a given center, where the planting, care, and use

of desirable fruits and vegetables were demonstrated. This plan met with a very heavy response, and from March to June, 1921, two and sometimes three groups were reached each week. Plants of the fruits being demonstrated were distributed whenever they were available. Products made at home from the fruit or vegetable demonstrated were exhibited on each occasion.

The following are representative of the various groups reached in this work: (1) Eighteen young Hawaiian women, nearly all of whom are married; (2) the members of the Housewives' League; 45 American-born high-school girls of Chinese, Portuguese, Japanese, and Hawaiian parentage, who were affiliated with the Young Women's Christian Association; (4) Filipino and Spanish women factory workers, for whom the services of an interpreter were required; and (5) 48 plantation people, the greater number of whom are white. The results obtained from this preliminary work clearly indicate the need of additional funds for furthering this type of extension activities among the women of Hawaii.

REPORT OF EXTENSION AND DEMONSTRATION WORK ON THE ISLAND OF HAWAII.

By R. A. Goff.

INTRODUCTION.

The extension agent for the island of Hawaii again visited as many as possible of those who are interested in farming, advising them where to secure the best seed and of the variety of seed that is best adapted to the elevation and locality of the farm, the kind of fertilizers to use, and the protective measures to take against crop pests. He also cooperated with organizations which are working to better agricultural conditions in Hawaii.

WORK IN EAST HAWAII DISTRICT.

Since the farmers who have 50 acres or less on the east side of Hawaii are interested principally in the growing of sugar cane, they do not use more than 1 acre for the growing of other crops. Plants or seeds of good varieties of banana, papaya, fig, and other fruits were distributed to them during the year, and a number started avocado and mango seedlings for future budding and grafting. About 50 trees were budded with scions that were received from the station in Honolulu and from D. H. Case, of Maui. Seed and young plants of the station's hybrid tomato, which is practically immune to attack by the melon fly, were secured from H. Shipman and distributed.

Edible canna roots and cassava cuttings were distributed for planting for hog feed, as were also elephant-grass cuttings for both dairy and hog feed. In the Hamakua, North Hilo, and Puna districts the possibilities of the pigeon pea and alfalfa were demonstrated on small plats.

WORK IN WAIMEA DISTRICT.

In the Waimea district, where the system of farming resembles the grain and stock farms of the Mississippi Valley, and where no sugar cane is grown, the station emphasized the necessity of raising live stock which can be fed crops that are grown on the farm. The practice of planting corn and potatoes only for the Honolulu market has resulted in a rapid depletion of the soil. Edible canna and elephant grass are crops that have shown themselves to be especially well adapted to the high altitude and heavy winds of this station. These crops together with corn will eventually form the principal part of the feed for live stock, and it will be necessary to purchase only enough milled feeds to balance the ration. During the year seedling trees were distributed for use as windbreaks to protect the growing crops from the high winds, which weaken their resistance to disease and increase the evaporation of soil moisture.

WORK IN NORTH KOHALA DISTRICT.

Since the erection of the new cannery in the North Kohala district the residents have planted considerable area in pineapples. Demonstrations in destroying weeds with arsenate of soda and in spraying useful plants with ferrous sulphate and ammonium sulphate to stimulate plant growth were given during the year. Corn and alfalfa seed were secured for planters who formerly raised rice. These men were forced to change their crops on account of the present low price of rice.

In the remaining districts of the island the extension work was conducted along similar lines with vegetable growers and with those who are interested in taro, sweet potatoes, and Irish potatoes.

DEMONSTRATIONS IN BUDDING AND GRAFTING SEEDLING FRUIT TREES.

Improved varieties of fruit trees may be obtained from the Honolulu nurseries only at an expense which the average homesteader does not feel that he can afford. The quarantine regulations, which are intended to prevent the spread of diseases and insect pests from island to island, prohibit the bringing in of any young trees until all the soil in which they were grown has been

removed. Owing to the expense of and the risk entailed in shipping, an attempt is being made to bud and graft as many desirable varieties of fruit trees as possible and to distribute them to farmers who agree to give them proper attention. The Hilo Boarding School has furnished, plowed, and harrowed a strip of land for this purpose. Approximately 200 mango and avocado seeds were planted during the year, and arrangements were made to obtain a further supply from local hotels and other concerns. It is planned to have boys, who are doing agricultural work in the Hilo Boarding School, actually do work in budding and grafting when the seedling trees are being worked over with improved buds.

BANANA-SHIPPING ACTIVITIES.

Trial shipments of from 50 to 200 bunches of bananas from Hilo to San Francisco direct and by way of Honolulu were continued once a month during the year. Arrangements were made with a firm in San Francisco to receive the fruit and to pay the local growers 3 cents a pound for the bananas when they were landed at the Hilo wharf. By this arrangement the growers assumed no risk for any deterioration of fruit occurring on board ship. Before being shipped the fruit was examined, selected, weighed in the field, and checked at the wharf. This work was carried on to enable the farmers having land adapted to the growing of bananas and unsuitable for sugar cane or pineapples to market their fruit outside of Hawaii where the market is not easily glutted. Reports from San Francisco state that the bananas arrive in good condition when they are properly wrapped.

FORAGE-CROP EXTENSION.

Some of the plantations have enlarged their demonstration plats of alfalfa. One plantation now has 2 acres and another has 5 acres. The alfalfa is cut 10 times a year and fed in the green stage because of the lack of facilities to cure it. Plantings of elephant grass are also being increased. This crop makes a good substitute for cane tops when the grinding season is over and the cane tops are no longer available. Pigeon peas are doing remarkably well up to an elevation of 1,500 feet. On the plantations where dairies are being installed there are being planted enough pigeon-pea plants to supply a large part of the soiling crops for the cows.

DISTRIBUTION OF AGRICULTURAL LITERATURE.

Agricultural page separates, which were edited by the extension division of the Hawaii station and originally published in one of the daily newspapers of Hawaii, were distributed to 1,200 interested

readers during the year. Fifty or more copies of the annual report and a number of bulletins were also sent to those requesting them.

COOPERATION WITH INDUSTRIAL SERVICE WORKERS.

During the year the owners and managers of some of the sugar plantations appointed industrial service workers to assist them in bettering the living conditions of their laborers. These service workers were instructed how to care for banana trees growing along fence rows and in gulches, and also how to care for the vegetable gardens and the swine of the plantation laborers. The instructions have been given in turn by the service workers to the laborers.

COOPERATION WITH BOY SCOUTS.

All the boys who wished to qualify for the boy scout merit badge in agriculture were given examinations by the station. Special demonstrations were arranged for the boys who were preparing to take this examination. Plants were propagated by budding, grafting, layering, and by seeds and cuttings. Insect pests and weeds were identified, and the methods for the control of each were demonstrated. Samples of the different kinds of local soil were collected and methods of improving the soil were discussed. Three kinds of seed testers were made and various kinds of seed were tested in them. Farm implements were identified and their uses were learned through the courtesy of a neighboring plantation.

COUNTY AGRICULTURAL FAIR ACTIVITIES.

During the year an effort was made to revive the Hawaii County Agricultural Fair. Committees, of which the extension agent served as a member, were appointed by the president of the Hilo Board of Trade. Plans of exhibition buildings were secured from the Maui County Agricultural Fair Association, and an appropriation of $25,000 was promised by the Territorial legislature provided that an equal amount should be raised on the island of Hawaii. The latter amount has been subscribed in part.

SCHOOL AND HOME GARDEN WORK.

The Star-Bulletin school-garden contest was continued during the year with greater interest than usual among the school children. The extension agent made three visits to the gardens of 19 schools, each garden of which was grown under the supervision of the school principals and in competition with the gardens of the other schools. He also visited 130 gardens which were being grown by the individual pupils at their own homes in competition with similar home gardens being grown by pupils in the other schools. He answered

as carefully as possible all questions asked by the young gardeners regarding fertilizers, seed, and the control of pests. Five of the school gardens and all of the home gardens were scored, and the winners in the different districts were given prizes by the Star-Bulletin. The remaining 14 school gardens were scored by another set of judges and also awarded prizes.

AGRICULTURAL EXTENSION MEETINGS.

The superintendent of extension and Profs. D. L. Crawford and L. A. Henke, of the University of Hawaii, spent a week on the island of Hawaii for the purpose of holding a series of agricultural extension meetings in the Hamakua, Hilo, and Puna districts. They received the hearty cooperation of the people of these districts, and as a result agricultural subjects were discussed in the schools during the day and at special meetings for the older people in the evening.

GLENWOOD SUBSTATION AND DEMONSTRATION FARM.

During the year the Glenwood substation and demonstration farm continued to raise live stock and also crops which have been found especially adapted to the Glenwood soil and weather conditions. The lease on both the original 16 acres and the 35 acres that were acquired later was renewed for 10 years. X. L. Helbush, the collaborator in immediate charge of the farm, is fencing in the 35-acre area to facilitate its use as a pasture. He is also repairing some of the old fences. When Mr. Helbush took charge over a year ago, the only dairy animal on the place was a purebred Guernsey bull. Since that time he has obtained nine cows and eight calves and heifers. The flock of purebred White Leghorns now numbers 300 laying hens and some young stock. Trap-nest records are being kept of the layers to determine which strains are the best. Hatching eggs have been sent to homesteaders in the various districts of this island and to poultrymen on the islands of Maui and Oahu. A purebred Berkshire boar, two Berkshire sows, and one grade Berkshire sow were added to the farm during the year. The boar is loaned for service to the farmers in the district, and the young stock is sold as breeding stock. Corn, potatoes, elephant grass, and sorghum seed which were planted have done well. Some of the crops were destroyed by heavy rains in January, 1921. The field of *Paspalum dilatatum*, where the sets were originally planted in rows, improved because of the stooling out of the hills. It is now almost a solid mass, forming a mat so thick that dairy animals can not break through in wet weather, as they continually do on the ordinary local pastures. This is the best pasture grass that has been introduced into the district because it grows especially well in wet weather and is drought resistant also.

HAIKU SUBSTATION AND DEMONSTRATION FARM.

By F. G. Krauss.

INTRODUCTION.

The official residence of the superintendent of extension work since the establishment of the extension division has been the Haiku substation and demonstration farm, which is situated a mile east of Haiku in the heart of the Kuiaha-Pauwela-Kaupakalua Government homestead tract, on the island of Maui. Much of the experimental field work of the Hawaii station has been carried on at this place, which is admirably located for demonstration purposes. Special attention has been given to the growing and feeding of new forage crops that have been found promising in the numerous variety tests made each year at the central station in Honolulu.

PINEAPPLE EXPERIMENTS.

Pineapple experiments were started in 1914, when the substation was established, and have formed one of its most important investigations. The pineapple industry in Hawaii is second only to the sugar industry in size. Its cultural problems have increased in proportion to its rapid development. The Haiku district is the center of an important part of the industry and has made the experimental work of the station of special value. Below are given the conclusions which are based on the original pineapple experiments begun in 1914 and continued to June 30, 1921. Other more recently inaugurated pineapple fertilizer experiments are being carried on in cooperation with the chemistry division.

SOILS.

Soil type is an important factor in pineapple production. The red and gray coarsely granulated and porous soils which characterize a large part of Hawaii's pineapple areas are unquestionably what may be termed typical pineapple soils, since they are best adapted to the crop. Such soils, while they may not prove fertile to other crops, are especially well suited for the pineapple crop, because they are naturally well drained and aerated. The black manganiferous soils abounding in the upland pineapple regions of Oahu, though of fine texture, are among the most productive soils when the plants are sprayed with an iron sulphate solution.

LOCATION AND LAY OF LAND.

Excellent pineapples have been grown on some parts of all the principal islands forming the Hawaiian group. Very fine fruit has been produced from near sea level up to 1,600 feet on both the islands

of Oahu and Maui. The most favorable altitude seems to be from 500 to 1,000 feet above the sea. New plants are thriving at an elevation of 1,800 feet in the Makawao district of Maui. The lay of the land does not seem to exert any marked influence on favorable soils. Fruit as fine as that which is grown on the slopes is produced on the extensive plain areas of Oahu.

TILLAGE.

The results obtained at the Haiku substation and observations covering a wide area elsewhere lead to the belief that the most detrimental single factor in pineapple culture is that of working or cultivating the land while it is wet. Land which produced some of the best crops when rationally tilled failed utterly in some experiments when it was plowed in a wet or excessively moist condition. Special stress should be laid on this phase of pineapple culture.

Subsoiling has been found very beneficial, both when applied before planting the crop and as intertillage after planting. High ridging of the plants, especially of the plant crop, is not recommended. Subsoiling and middle busting between the rows, and releveling the soil so that gentle ridges are maintained, provides subdrainage, aeration, and a mellow soil. Severe ridging fails to provide such conditions.

PLANTS.

One can not exercise too great care in selecting the plants. Only strong, healthy parent stock, preferably the plant crop and first ratoon crop, should be considered for planting. The planting of crowns, slips, or shoots will produce equally good crops, other conditions being favorable (Pl. X, Fig. 1). The plants, however, must be gathered at the proper state of maturity. Immature or overripe planting stocks will not produce good crops no matter how fine the parent stock or the soil. When crowns from the tops of ripe pineapples are used, one has, of course, less opportunity for choice, but they should at least be carefully culled before they are planted.

The amount of curing that is necessary before setting the plants depends upon the season and the soil. In midsummer, if the season is dry and the soil is in good tilth, the plants should be set out without being cured. Under these conditions the plants need not be as mature as those planted in a cooler and wetter season. If the plants are over mature they should be adequately stripped of their basal scales or leaves. When shoots are to be planted the butt should be cut away. A sharp knife should be used for this purpose, because hacking may cause bruising.

Pineapple plants should be carefully handled in transit, and never be thrown into large piles where heating of the mass can take place.

FERTILIZERS.

There seems to be little or no doubt that stable manure gives the best results in improving soils which are deficient in plant food or that are of poor texture, or both. Pineapple cannery waste and green-manuring crops are practically of equal value. Chemical fertilizers, however, judging from all the reliable data at hand, seem to produce very uncertain and anything but uniform results. Experiments during the year with nitrogenous fertilizers, including potassium nitrate, ammonium nitrate, ammonium phosphate, ammonium sulphate, sodium nitrate, and dried blood, applied in single and fractional doses and totaling from 200 to 400 pounds per acre as a side dressing apparently have exerted only very slight benefits in developing the plants, which have now (June 30, 1921) been planted eight months. Of all the fertilizers, ammonium sulphate seems to have exerted the greatest influence. In fact, this ammonium salt has given good results in a wide territory.

All the virgin soils of Hawaii give better results in connection with pineapple culture than do soils from which even only one crop has been removed. These results are due to the changes that are brought about in the soil by the destruction of the delicate and complex humus matter. The apparent need of organic matter, in proper amount and kind, led the station to undertake a series of experiments with old pineapple land. The results of these investigations indicate the need of turning under all residual crops of the pineapple and supplying organic matter with green-manure crops turned under at the proper season. The following recommendations for the handling of old pineapple lands, with a view to their rehabilitation, are based on data accumulated to date (June 30, 1921):

As soon as the last harvest of any planting cycle is completed, usually in the late fall, the ground should be prepared for planting pigeon peas. The space between the old pineapple rows should be subsoiled, sufficient power being used to break the soil deeply. The subsoil plow should then be followed by a middle buster, throwing the soil to either side. This will cover the weeds and force débris away from the center. If the ground is very dry and cloddy, it should be allowed to rest until after a good rain. Then a one-horse cultivator should be run along the bottom of the open furrow that is left by the middle buster. Two or three workings may be advisable to prepare a suitable seed bed. If the several cultivations are done at intervals of a week or two, successive crops of troublesome weed seedlings will be destroyed and future cultivations will be reduced to a minimum. One row of the pigeon pea seed should be planted between each two rows of the old pineapple plants. A seed drill that is drawn by a horse should be used for this purpose. Ten pounds

of seed will be required per acre. The plants make only spindling growth at first, but after two or three months they begin to close in over the old pineapple débris. At the end of the year nearly all of the pineapple stumps will have rotted. This decayed vegetable matter will mulch and manure the pigeon peas and cause them to make a luxuriant growth. The pods should be picked if there is a demand for seed; otherwise the crop can be pastured or harvested for hay. In any event the crop should be left growing for a period equal to that of the pineapples preceding it. It should then be turned under for green manure and a new crop of pineapples planted. By this time the land will be restored as fully as possible and very economically. At Haiku the pigeon pea crops have yielded an average of approximately $100 net profit per acre a year (Pl. IX, Fig. 1).

PRODUCTION OF STARCH ON A SMALL COMMERCIAL SCALE FROM ROOT CROPS AND CORN.

During the year tests were made with edible canna, sweet potatoes, taro, corn, and two varieties of cassava for the production of starch. All of these crops, with the exception of 20 tons of cassava roots which were purchased at $10 per ton, were grown on a field scale at the Haiku substation. Commercial quantities of starch were produced from these crops and residues (by-products from the manufacture of the various starches) in sufficient quantity to conduct satisfactory feeding experiments with swine and poultry.

The recovery of starch from all the crops tested, with the exception of corn, which was a failure, was approximately 20 per cent, or 400 pounds of air-dried starch per ton of roots as they were weighed at the mill. This is not a very efficient extraction, but it was very fair considering the crude methods that were used in the process. It also emphasizes the importance of utilizing to the best advantage the residue, which retains approximately half of the total starch. This probably largely accounts for the high-feeding value of the residue when fed to swine. The starch was sold at an average price of 15 cents per pound. The remaining pulp or residue, which averaged about 1,600 pounds from each ton of original material as macerated, was made into feeding rations, both raw and cooked, for swine and poultry. These feeding experiments have indicated that the feeding value of the cassava and sweet-potato residue, calculated on a water-free basis, is fully equal to that of corn, when its proportion does not exceed 50 per cent of the total ration fed. This is true especially when either of these two kinds of residue are steam cooked and mixed with corn meal, rice polish, wheat bran and middlings, alfalfa meal, or with finely ground pigeon-pea meal (whole plant), and the whole fortified with from 5 to 10 per cent of blood meal or high-

grade tankage. Skim milk and skim-milk substitutes, such as dissolved powdered skim milk and semisolid buttermilk, gave results approximately equal to those obtained from feeding tankage or dried blood, especially with younger pigs. Owing, however, to the scarcity and relatively higher cost of the protein equivalents in milk, it was thought more economical to feed the slaughterhouse products. This probably would not hold good where cheap skim milk is available. The cassava and sweet-potato residues were found to be very palatable to hogs when fed either raw or cooked, as was also the limited amount of taro available, but the edible canna and Irish-potato residues were eaten only when cooked and mixed with standard mill feeds. Poultry ate only limited amounts of any of the residue feeds when ample grain was available, but seemed to relish it when it was fed in limited amounts. All animals fed in these experiments were in dry lots. In two 100-day feeding tests, 5 mature hogs and 10 pigs, the latter averaging about 80 pounds at the beginning of the test, gained from 0.75 to 1.75 pounds per day when fed a ration in which cassava or sweet-potato residue resulting from the starch manufacture did not exceed 50 or 60 per cent of the total ration. The feed was well balanced, however, with part of its protein in animal form. These gains compare favorably with the results obtained over a long period from feeding an equivalent of corn. When the residue is fed much in excess of 50 per cent, the animals, especially the older ones, become logy and somewhat pot-bellied and the flesh apparently loses its firmness. It has been estimated that, on the basis of carbohydrate content (starch), 5,200 pounds of the residues is equivalent to 2,000 pounds of corn.

From the data given above and a rough determination of the costs that enter into the manufacture of the starch, it would seem that an efficient utilization of the by-products should cover all costs of manufacture. The following is a summary of the cost of manufacturing 400 pounds of cassava starch and 1,600 pounds of by-products at the Haiku substation, and the value of the finished product.

Cost of manufacturing cassava into starch and value of products.[1]

Cost.		Value of the product.	
Delivered to mill, per ton	$10.00	400 pounds starch (at 10 cents per pound)	$40.00
Washing and peeling roots, per ton [2]	2.50	1,600 pounds residue as it came from the mill (at $10 a ton)	8.00
Grating washed roots to a fine pulp, per ton [2]	2.50		
Attending to sieves, water-sprinkling device, and settling tanks [2]	2.50	Total value	48.00
Draining settling tank, removing 400 pounds starch, drying, bagging [2]	2.50	Total expense	25.00
Overhead expenses, including water, rental, and depreciation	5.00	Net profits per ton of roots	23.00
Total	25.00		

[1] These figures are largely based on the use of the farm-made equipment.
[2] Labor of one man per day.

The above-mentioned figures are considered conservative, and it is thought that the by-product when fed to swine can be made to cover the entire cost of manufacturing the starch, including the production costs of the raw product.

Starch was also extracted in small commercial lots from sweet potatoes, edible canna, taro, and Irish potatoes.

These experiments were conducted to determine the practicability of the small farmer and the man of limited capital producing starch from his own products and possibly from those of his neighbor.

The growing of cassava, sweet potatoes, edible canna, and possibly other starch-producing plants, and their manufacture into starch, together with the utilization of the residue, can, it is thought, be made a very profitable business if starch continues to sell at 10 cents or more per pound and hogs at 18 cents per pound live weight.

The cost of the starch-extraction equipment at the Haiku substation, exclusive of power and building, was $250. The cost of a 5-horsepower engine to operate the machinery would be about $250, and a rough shed 22 by 24 feet could be built for about $500. The total cost for a small starch factory should not, therefore, exceed $1,000.

BREEDING AND FEEDING EXPERIMENTS WITH LIVE STOCK.

Breeding and feeding experiments and demonstrations with several classes of live stock have been carried on at the Haiku substation and demonstration farm since its inception. One of the most important of these experiments is the work with poultry, which is being conducted by the superintendent of extension and his family.

POULTRY.

In 1913 a flock of 100 selected Single Comb White Leghorn hens (C. H. Wyckoff's Aurora strain) headed by 4 pedigreed male birds, and 24 Plymouth Rock pullets (Owen Farm, Vineyard Haven strain) which were mated to two pedigreed cocks of the same breed, were brought to the Haiku farm for use as foundation stock. All of these fowls had been line bred for several years, no new blood having been introduced into the flock in at least 10 successive years of breeding. From 60 to 200 chickens have been raised each year, and flocks of 100 and 200 mature hens have been maintained through a period of seven years. The stock to-day is as virile and prolific as were its progenitors in the beginning of the 10-year period. This would seem to indicate that close-breeding is not always detrimental. Furthermore, crosses and reciprocal crosses have been conducted between the two breeds for a number of years to establish a type of fowl that would be especially adapted to Hawaiian conditions. No very

uniform new strains of crosses have as yet been effected, but some beautiful specimens have been developed. None of the matings of the many crosses effected during the past five years has resulted in uniform vigor in all or even in most of the progeny. As a matter of fact, in so far as the experiments have progressed, the greatest uniformity in vigor, as well as in all other qualities, has been produced in the line-bred fowl. Stress should be laid on the importance of selecting blood lines and types that blend favorably. Undesirable characteristics must be avoided, and desirable characteristics must be intensified. The station knows of no more direct and certain method of establishing uniformity of type than by the use of a rational system of fairly close line-breeding.

Careful feeding and egg records have been kept of 60 select layers of the Single Comb White Leghorn breed during the past seven years. The lowest average annual yield per hen, based on the whole flock's production, was 138 eggs, and the highest, 141 eggs. On the whole, the tendency has been toward improved production. Sixty hens laid 7,796 eggs during the fiscal year ending June 30, 1918, and 8,869 eggs during the fiscal year ending June 30, 1921. The production of eggs in the 1917–18 period was fairly uniform during the two half-years periods. In the 1920–21 period twice as many eggs were laid in the last half-year period (January 1 to June 30, 1921) as in the first half-period (July 1 to December 31, 1920). The first half of the 1918 period was very dry, and the latter half was very wet, the rainfall for the two 6-months periods being 23.28 inches and 68.58 inches, respectively, or 91.86 inches for the 12 months. In the first half of the 1921 period 28.99 inches of rain fell, and during the second half of the period 32.76 inches, or a total of 61.75 inches for the 12 months. Whether wet and dry seasons affect the egg laying of the fowl can not be determined from the limited data at hand, but it is thought that the dry season is more favorable than the wet season for egg laying.

All the flocks under consideration received the same feeding rations during the several years that they have been under test. The morning feed is a standard commercial laying mash containing dry nutrients in the following proportions: Moisture, not over 10 per cent; protein. not under 20 per cent; carbohydrates, 49 per cent; fat, 4.5 per cent; ash, not over 11.5 per cent; and fiber, not over 5.5 per cent. A slightly moist crumbling mass can be had by mixing 6 pounds of the above with 4 pounds of clabber milk. At night the flocks are given 5 pounds of scratch feed consisting of various parts of standard commercial scratch feed, supplemented with cracked corn, pigeon peas, cowpeas, soy beans, and other farm-grown grains. At noon the flock is fed liberal quantities of one or more fresh, green feeds, including beet

tops, and roots, cassava roots, sweet potato tops and tubers, alfalfa, finely minced sugar cane, and the like. Grit, oyster shell, and charcoal, and fresh water are kept constantly before the flocks. The 60 hens have been maintained continuously on a one-tenth acre lot planted to pigeon peas, intercropped with papaya trees, and Tabasco pepper bushes, which supplied abundance of shade and some supplementary feed and condiments. Whenever soft-shelled eggs appear, a sufficient quantity of fresh lime is slaked in the drinking water to make a saturated solution.

The poultry work, which is being carried on by the New Era homestead farm, under the auspices of the Haiku substation, is one of its most profitable undertakings. The average net profit per hen per annum over a period of five years approximates $2.25. In two successive years, both the White Leghorns and the White Plymouth Rocks have carried off first honors at the Maui County Agricultural Fair.

SWINE.

The New Era homestead farm, under the auspices of the Haiku substation, has maintained from 1915 to 1920 a herd of registered Berkshire swine, consisting of 10 brood sows and 2 herd boars. Breeding and feeding experiments and demonstrations similar to those carried on with poultry were undertaken with swine. As a result of these experiments one or more grand championships were won at three Maui County agricultural fairs against the keenest competition of imported and locally bred stock.

DAIRY HERD.

During the greater part of the station's existence a herd of from 4 to 12 purebred and high-grade dairy Jersey cows were maintained for feeding experiments. The results of these experiments were published in one of the local daily newspapers, and the complete data will probably be issued by the station in bulletin form. The experiments have shown that pigeon peas as a roughage, and dried and ground cassava-root meal as a concentrate, have a high feeding value; and that, on the other hand, fresh sugar cane, whether fed whole or finely minced, has a low feeding value for milk cows. Fresh sugar cane is very palatable and may be fed to some extent, provided that it is mixed with other roughage such as cowpeas, pigeon peas, and the like, but it can not be profitably utilized as the sole roughage for dairy cows under high production.

GOATS.

Breeding and feeding experiments with goats have been under way at the station for one year only. The present herd consists of

Gretel's Son, No. 1554,[9] a purebred registered Toggenburg buck of very fine breeding; two half-breed Toggenburg does, litter mates that were bred to the above-mentioned buck; and the progeny of these two does. (Pl. IX, Fig. 2.) The progeny, two pairs of female kids, were dropped on April 9 and 10, 1921. El Chivar's Hertha, No. 1023, a fine, registered Toggenburg doe having a record of 1,880 pounds of milk and 58 pounds of fat in her fifth lactation period, was unfortunately killed by falling from a cliff. A number of outside grade and native does were bred to the herd buck, and the progeny of four of these does was recorded for further observation.

During the year numerous comparative tests were made of the pigeon pea and other crops to determine their value as green and cured feeds for milk goats. The results show that the pigeon pea is extremely nutritious and palatable and that it is a most efficient and economical roughage feed. It is unreservedly recommended for planting for this class of stock. Corn meal and mill feeds were found to be excellent concentrates.

MISCELLANEOUS CROPS.

Three varieties or strains of sugar beets were grown at the Haiku substation during the year and by several collaborators on the islands of Oahu, Hawaii, and Maui. The results of the plantings at Haiku were very satisfactory. The beets were planted on old pineapple land to which a mixture of equal parts of super and reverted phosphate was applied at the rate of 1,000 pounds per acre in the drill at the time of planting the seed. The beets were planted on November 24, 1920, and harvested on June 23, 1921. The following table gives the results of the variety test with sugar beets:

Results of variety test of sugar beets.

Strain.	Weight of green tops per acre.	Weight of roots per acre.	Calculated sugar yield per acre.[1]
	Pounds.	*Pounds.*	*Pounds.*
Michigan	5,241	24,458	4,594
Klein Wanzleben	12,229	27,952	4,918
Idaho	6,988	26,205	4,054

[1] Owing to an oversight the beets for analysis were not weighed separately when dug. In the week that intervened before analysis could be made, it was estimated that the beets lost 15 per cent moisture. The sugar yields have been calculated on this basis.

As a dairy feed, these beet roots and their accompanying tops have made a most excellent feed, and they should be given at least a trial planting by all dairymen who are well located. Had the season

[9] This goat is a half brother of California Gretel, the milk goat which established the world's record in 1917, when she produced 2,941 pounds of milk.

been favorable in regard to rainfall, or had facilities for irrigation been available, it is thought that much larger yields would have been produced.

Forage-crop work continued to be one of the major projects of the substation (Pl. X, Figs. 1 and 2). The Merker and Napier grasses, both of which have gained rapidly in favor during the last three years, are ready for cutting long before either the Uba cane or the best forage sugar cane is mature. The variety Yellow-Tip, on account of its heavy "lallying" or branching habit, is considered the best forage sugar cane. The sugar-cane varieties are very much relished by the substation cattle, and they are considered of high value as forage, especially if harvested at the best period of growth and thoroughly shredded. The following table shows the yields obtained at the Haiku substation and demonstration farm from new select plantings made on November 24, 1920:

Yield in pounds per acre of green forage harvested from crops planted on November 24, 1920.[1]

Variety.	First cutting, Mar. 28.		Second cutting, May 31.		Third cutting, June 27.	
	Fertilized.	Unfertilized.	Fertilized.	Unfertilized.	Fertilized.	Unfertilized.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Yellow-Tip cane	40,800	34,850	38,250	26,350	(2)	(2)
Uba cane	34,850	22,590	24,650	8,500	(2)	(2)
Napier grass	31,450	23,800	36,850	13,600	31,400	19,350
Merker grass	19,550	17,000	27,250	14,450	30,750	23,850

[1] Calculated to acre yields from 200-foot rows, spaced 5 feet apart.
[2] Not harvested.

The first cuttings of all the grasses were made approximately 100 days from the time of planting. At this period the Yellow-Tip cane gave the heaviest yields, totaling approximately 20 tons of green forage per acre. Uba cane gave 17 tons, and Napier grass 15½ tons, and Merker grass approximately 10 tons. The latter grass grows fastest in height, but is spindling in its growth and deceptive as to yield. In the younger stages of development, and when it is well established, Merker grass closely resembles Napier grass. The former flowers several weeks earlier than the latter, and at that stage of its development its stems are harsh and bamboolike. Napier grass is much more succulent throughout its development, and it is considered the better of the two grasses. Both grasses make a much better growth during the dry weather than do the sugar canes.

Edible canna has shown itself to be a valuable forage crop during the past half year of extremely dry weather. When fertilized with 250 pounds of phosphatic fertilizers per acre, applied in the furrow

at the time of planting, the plats yielded twice the quantity of forage and tubers that the unfertilized plats produced. The average yields during the past summer were 20 and 10 tons, respectively, of tubers and about an equal amount of leafage. Both the foliage and tubers make excellent feeds for dairy cows, and when cooked the tubers are fairly good for pigs.

The cassava crop has maintained a high place among the many forage crops being grown at the substation. The Wiebke variety, which was introduced from the island of Kauai and grown in a comparative test with eight other varieties, continues to hold its own as to quality and yield. However, at least two of the varieties, which were imported from Java through the efforts of Prof. J. F. Rock in 1918, are very promising on account of their large yield.

Culinary and field beans, Irish potatoes, and corn continue to be important crops, especially from the standpoint of developing pure and improved strains. The corn crop of the year was the poorest in the history of the station, owing to unfavorable conditions. A comparison was made to determine the weevil resistance in storage of the New Era Bantam Yellow Flint poultry corn (S. P. I. No. 45903) with two varieties of local yellow dent and one white dent corn. The yellow flint corn showed comparatively little injury from weevil, but the dent varieties were very much eaten at the end of a 4-months' period of serious infestation.

After many tests with pop corn, some success was had for the first time during the year. Seven varieties were tested in comparison, and the following results were obtained from 100-foot rows of each variety: Black Beauty, $4\frac{1}{2}$ pounds of ear corn; Yellow Hull-less, $2\frac{1}{2}$ pounds; White Rice, $1\frac{3}{4}$ pounds; and Queen's Golden, $1\frac{1}{4}$ pounds. Australian Hull-less, New Golden Rice, and Pure Gold each yielded a fraction over a pound. The yields were small, owing to an extremely unfavorable season for corn.

HALEAKALA SUBSTATION AND DEMONSTRATION FARM.

By F. G. Krauss.

INTRODUCTION.

The Haleakala substation and demonstration farm is situated on the island of Maui, in the heart of a promising homestead tract on the slopes of Haleakala, a giant extinct volcano. The land on which the substation and demonstration farm is located consists of approximately 50 acres that were set aside by the Territorial Commissioner of Public Lands in 1918; and through the efforts of Gov. Charles

FIG. 1.—OLD PINEAPPLE LAND REJUVENATED BY PLOWING UNDER PIGEON PEAS. LEFT TO RIGHT, PLANTED WITH PINEAPPLE CROWNS, SLIPS, AND SUCKERS.

FIG. 2.—STATION HERD TOGGENBURG MILK GOATS FEEDING ON ALFALFA. HAIKU.

FIG. 1.—FORAGE PLANT INVESTIGATIONS. TWO ROWS ON LEFT, YELLOW-TIP CANE; CENTER ROWS, UBA CANE; RIGHT, NAPIER OR ELEPHANT GRASS.

FIG. 2.—NAPIER OR ELEPHANT GRASS ON LEFT. MERKER GRASS ON RIGHT. THREE CUTTINGS OF EACH AS COMPARED WITH TWO FOR CANE VARIETIES SHOWN ABOVE.

J. McCarthy,[10] the sum of $5,000 was appropriated for the construction of the farm buildings which are now being used by the collaborator having immediate charge.

The object of this substation and demonstration farm is to conduct experiments and demonstrations for the benefit of new farmers, many of whom take up homesteads without the necessary capital to justify them making what may prove to be costly experiments in crop production. Climatic conditions vary so in the different districts that what may succeed in one section may not succeed in a neighboring locality. Experiments at the substation will show in the shortest time possible just what can be produced under the somewhat peculiar conditions of soil, rainfall, elevation, and exposure to wind. The establishment of this substation therefore marks an important advance in the development of the homestead districts of the islands.

MISCELLANEOUS PLANTINGS.

Owing to the very heavy rains which fell in the early part of the season and to the severe drought which followed, the year was most unfavorable for the crops growing at Haleakala. Notwithstanding these facts, an acre of pigeon peas that were planted in the fall of 1919 has continued to thrive and to seed heavily. In the fall of 1920, half an acre was planted in Italian lupines, which have made satisfactory growth and have yielded over 200 pounds of prime seed. The crop residue was plowed under as green manure. Edible canna, though it has made slow growth, has produced a fair yield of edible tubers. Three 100-foot rows, each of which was set 5 feet apart, yielded 385 pounds, or at the rate of about 6 tons of tubers per acre during the year. It is thought that closer planting and a longer season for growth at this high elevation would result in a still larger yield. Fully 20 tons per acre have been produced at the Haiku substation at an elevation of 500 feet, and 40-ton yields have been recorded at the central station. The tubers when cooked make an excellent hog feed, and the foliage, that is, the stems and leaves, which about equal the weight of the tubers, make excellent feed for dairy cows. Previous experiments with two varieties of cassava, when compared with the results obtained with edible canna, seem to indicate that the edible canna is the more profitable crop to grow on these lands. Several unsuccessful trials were made with sweet potatoes during the year. The failure is thought to have been caused by the land, which is very much exposed to the elements, becoming very

[10] Governor McCarthy set aside representative units in Territorial homestead tracts for demonstration farms to be used for the benefit of the homesteaders of the particular tract in question. The Haleakala substation and demonstration farm is located on one of these tracts.

cold in the rainy season and excessively dry in summer. It is planned to test several varieties of sweet potatoes next season, both with and without fertilizers. In these experiments advantage will be taken of the shelter provided by well-established rows of both Uba cane and pigeon peas. Observation leads to the belief that success on a large portion of these lands depends upon shelter belts. Eucalyptus or other trees should be planted on the windward boundaries, and rows of Uba cane and pigeon peas should be spaced throughout the fields so as to permit of intercropping with less hardy crops.

Two plantings of pineapples, including crowns, slips, and shoots that were selected from both the low and the high lands of the Haiku district, have been made at the Haleakala demonstration farm. The first planting was made in September, 1919, and proved a total failure. The second planting, made in August, 1920, is growing slowly, due, no doubt, to the unfavorable seasons and the high altitude (2,000 feet). The deep gulches, which are a striking feature of these islands, have been found admirably adapted to banana culture. During the year there was set out an initial planting of 600 select dwarf Chinese or Cavendish banana plants and a few available plants of the Bluefields variety. It is intended to extend these banana plantings on account of the increase in the demand for choice fruit and the improvement in the prices paid for them. Maui should become an important district for growing and exporting bananas when transportation facilities between Hawaii and the mainland improve.

Dry-land taro and vegetables in large variety also were found to thrive much better in these protected and fertile mulch lands than on the raw, exposed uplands. Large crops of several species of wild Rubus, the "akala" berry of the Hawaiians, and an excellent blackberry are maturing in great abundance in the native forests near by. If these crops can be cultivated for commercial purposes, the once supposedly waste lands will prove valuable assets to the Territory.

CORN VARIETY TEST.

In February, 1921, 11 varieties of corn, including the Kula type, were planted on 8 acres of land. Part of the area planted to each variety was fertilized by the application of 500 pounds per acre of of a mixture consisting of equal parts of acid phosphate and reverted phosphate. This mixture had given the most benefit in former experiments and again proved very effective. Only the Kula type of corn thrived, and this on the land that was fertilized. The results of this trial and of previous tests, made both at the demonstration farm and in experiments carried on in cooperation with some of the farmers in the vicinity, would indicate that on these lands farmers

should adhere to the long-established Kula type of corn, and to apply in the drill rows, at the time of planting, 500 pounds of a fertilizer compound composed of equal parts of super and reverted phosphate.

POULTRY.

Poultry does exceptionally well on the open range of the northern, middle slopes of Mount Haleakala, where the demonstration farm is located, and success has been had with flocks of the Buff Orpington, Light Brahma, and Black Spanish fowls, as well as with the Bronze Turkey. All of this stock fairly revels in the pigeon-pea rows, which protect them from the raw winds of winter and the scorching sun of summer, both of which are detrimental to poultry. Furthermore, the pigeon-pea plant yields a nutritious grain and green vegetable matter at a season when most other herbage is scarce. Under these favorable conditions it seems fully justifiable to extend the poultry projects.

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HAWAII AGRICULTURAL EXPERIMENT STATION
HONOLULU, HAWAII

Under the supervision of the
UNITED STATES DEPARTMENT OF AGRICULTURE

Washington, D. C. July 11, 1924

REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION, 1922.

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SUMMARY OF INVESTIGATIONS.

By J. M. WESTGATE, *Agronomist in Charge.*

During the fiscal year 1922 the station continued to emphasize the necessity of furthering the diversified agricultural industries of the islands by promoting the production of many new and improved forage crops, fruits, and vegetables and by working out rational cropping systems suitable to sugar cane and pineapple growing.

Introducing such new plants as are believed to be of economic value and improving many of the useful fruits now under cultivation in the Territory by breeding and selection work has constituted a major project of the horticultural division. The best of these will be propagated and distributed to growers throughout the Territory. During the year, 232 different varieties were received and 22,100 plants of improved and promising strains distributed.

Agronomic investigations were carried on with root, green-manuring, grain, and forage crops, and also with aquatic crops of economic importance and oriental origin. To meet the needs of those combining poultry raising with vegetable gardening, the agronomist devoted part of his time to poultry work, introducing breeding stock of high egg-producing capacity, and conducting caponizing and culling demonstrations.

In the chemical division investigations were conducted to determine the most profitable utilization of surplus fruits which are prevented by quarantine regulations from being exported. The dehydration of certain fruits and vegetables and the making of jams, jellies, and preserves promises to become of commercial importance.

The resignation of the superintendent of extension on November 1, 1921, necessitated considerable readjustment of the various activities of the station and the assignment of certain phases of the department to other workers, pending the filling of the vacancy.

Many of the projects of the Haiku substation were brought to a satisfactory close and others were transferred to the Haleakala substation and demonstration farm for continuation. A few of the projects are being carried on in connection with the station by the new manager of the farm on which the Haiku substation was located.

The extension agent for the Island of Hawaii devoted the major part of his time to orchard work and to the improvement of pastures on the various cattle ranches. During the year he traveled 11,200 miles, mostly by automobile, and visited 1,500 farmers, in addition to distributing bulletins, vegetable and fruit seed, young nursery stock, and cuttings and suckers to homesteaders, ranchmen, and plantation managers. Much assistance was given in ordering varieties of seed, in selecting seed in the field, and in applying the right amount of fertilizer to the different soils of the various localities.

Home demonstration work was continued on practically the same scale as last year, the home economics demonstrator again working part time as collaborator and operating through various local organizations, assuring large interested audiences.

The station made a representative exhibit of various phases of its work at the fourth annual Maui County Agricultural Fair, which was held from October 15 to 23, inclusive, and several members of the staff acted as judges on a number of the important fair committees.

REPORT OF THE HORTICULTURAL DIVISION.

By W. T. Pope.

MISCELLANEOUS FRUIT INVESTIGATIONS.

BANANAS.

Renewed activity in banana growing is very apparent, and in many places small plantations are starting. No large corporations have as yet entered the industry. Approximately 18,000 bunches per month were shipped to the markets of the mainland during the year, and prices fluctuated considerably, the net wholesale price per pound f. o. b. Honolulu wharf ranging from $0.027 in July and August, to $0.043 in January and February. The price of offshoots of the Chinese banana ranged from $15 to $20 per hundred, and Bluefields, which are rarely available, were even higher. Brazilian and Ice Cream sold for $5 to $10 per hundred.

The station is growing 26 different varieties of bananas in a sheltered valley at the Tantalus substation and plans to select promising varieties from this collection for determination as to their commercial possibilities. Kona Maiamaoli, an excellent banana which has been grown for generations in the Kona district is thought to have a great commercial future. (Pl. I, fig. 1, and Pl. II, fig. 1.) The Chinese variety is considered most desirable of all for planting in the lower elevations and in gardens, being a low-growing plant which produces large fruit early in the season. Offshoots from a small planting at the central station were distributed during the year to school and home gardens. Bluefields is a good shipper, but the

plant is tall growing and should be planted in localities that are relatively free from strong winds. Brazilian and Ice Cream withstand considerable wind, but are grown for local consumption only. Popoulu Kaio is an excellent native variety. (Pl. I, fig. 2, and Pl. II, fig. 2.) The native varieties, which are classed chiefly as cooking bananas, are raised for local use only.

PAPAYAS.

The papaya is more in demand than ever in Hawaii and brings such high prices on the market that most dealers retail their fruit by the pound.

The papaya investigations, which were begun by the station about two years ago, are already showing interesting results. Seedlings of the Solo variety, which is composed of several strains each differing in shape of fruit, have just come into bearing, producing fruit of superior form and quality to that of the parent. (Pls. III and IV.) The trees conform to the ideal in that they have short, stout trunks and begin early to bear an abundance of fruit. In many instances, 11-months old trees support a weight of 40 to 70 pounds.

It is quite evident that papayas of very high quality can be produced by proper methods and that the nature of the flesh of the fruit changed by direct cross-pollination, just as is the case with the seed. It is hoped that the monœcious type can be developed to such an extent that choice characters will not be frequently changed by cross-pollination.

Grafting methods were not satisfactory to any great extent in the production of standard fruit, but when lateral branches were planted as cuttings the fruits produced equaled those of the parent tree in quality. The terminal growth may be removed from 2-year old trees which bear their fruit too high to permit of convenient picking. This will cause lateral buds to sprout from some of the leaf scars along the trunk. When these laterals attain a length of 1½ or 2 feet they can be removed and set 8 or 10 inches deep in coarse gravelly soil. Given careful attention, they will soon root and develop as new trees, producing fruit of excellent quality. Some trees produce only few laterals, while others develop 25 or even 50.

Papayas of very fine quality may be produced from selected seed for general purposes provided they are given good culture. The seedlings should be planted 8 feet apart each way in rows in rich soil with good drainage. The soil about the plants should be enriched with thoroughly decomposed barnyard manure at the time of planting, and the young trees given clean culture and plenty of water if a large yield of well-flavored fruit is to be expected.

During the year seed of the Dapitan papaya germinated, and the young seedlings were set in a trial plat. This variety was received from the Philippine Islands.

CITRUS FRUIT.

The citrus orchard, which now contains 160 trees representing 35 different varieties, is located on the southeastern slope of Punchbowl Mountain where the soil is of tufa lava origin. This orchard was fertilized with barnyard manure and given thorough cultivation

during the spring, summer, and fall months. Early in November it was sown with mungo beans (*Phaseolus mungo*), 150 pounds of seed being broadcasted per acre, and in April the cover crop was turned under. The treatment greatly improved the soil, and the Kusaie lime and several varieties of orange and lemon trees bore heavy crops of fruit as a result.

After making an extended survey of the orange trees growing in the district of Kona, the horticulturist has succeeded in obtaining bud wood from what is thought to be the best Hawaiian (Polynesian) orange tree for budding on seedling stocks of sour orange and rough lemon trees growing at the central station. The tree is vigorous and prolific and produces large, smooth-skinned, sweet, juicy fruit containing few seeds. Several consignments of the bud wood have been propagated for distribution. Cooperative experiments are being carried on with W. D. Ackerman and W. H. Greenwell, who have set out an acre of these selected budded trees in Kona.

About 50 sweet shaddock trees have been propagated from a tree producing fruit of very fine quality. The original tree is owned by Mr. and Mrs. Henry A. Gehring, Honolulu, who kindly permitted the removal of graftwood that this choice fruit might be made available to others.

AVOCADOS.

Of the 40 budded varieties of avocado trees in the orchard at the Tantalus substation, 14 are of the Popenoe Guatemalan collection. These trees are growing without irrigation at an elevation of 1,000 feet. Some are now past their third year, six have blossomed, and two are setting fruit. Bud wood of the varieties Northrup, Taft, Solano, Puebla, Harmon, Fuerte, and Trapp, which are in common cultivation in California, has been received and successfully propagated. Fully 85 varieties are now under trial at the station, and 5 cooperative experiments with private owners are being carried on.

An effort is being made to group varieties fruiting at different seasons, so that the fruit may be in season throughout the year instead of being confined practically to the summer months. In the Kona district some trees of the West Indian type ripen their fruit during the winter months, while on Oahu the trees usually ripen their fruit in the summer. Among those producing fruit in the fall, winter, and spring are Beardslee (Ables), Macdonald (Pl. V, fig. 1), Nutmeg, Kalua, Wilder, Kinau, and the Case avocado (Pl. VI, fig. 1), all of which have considerable local reputation for quality.

During the year the station propagated over 800 seedlings for use as rootstocks in further experimental propagation work.

One of the important observations noted in connection with avocado growing is the frequency with which seedlings, the progeny of good varieties, develop fruit of good quality. In many instances the fruit is superior to that of the parent.

MANGOES.

Ninety trees of various varieties of mango are under trial, the most promising of which are being propagated for distribution. The least desirable trees have been removed to give space to the remainder and to permit of the cultivation of the orchard. Pruning and culti-

FIG. 1.—BANANA, NATIVE VARIETY KONA MAIA-MAOLI. ONE OF THE BEST HAWAIIAN COOKING BANANAS.

FIG. 2.—BANANA, NATIVE VARIETY POPOULU KAIO. BUNCH MEDIUM SIZE; AVERAGE WEIGHT, 30 POUNDS. USED AS FRESH FRUIT OR COOKED.

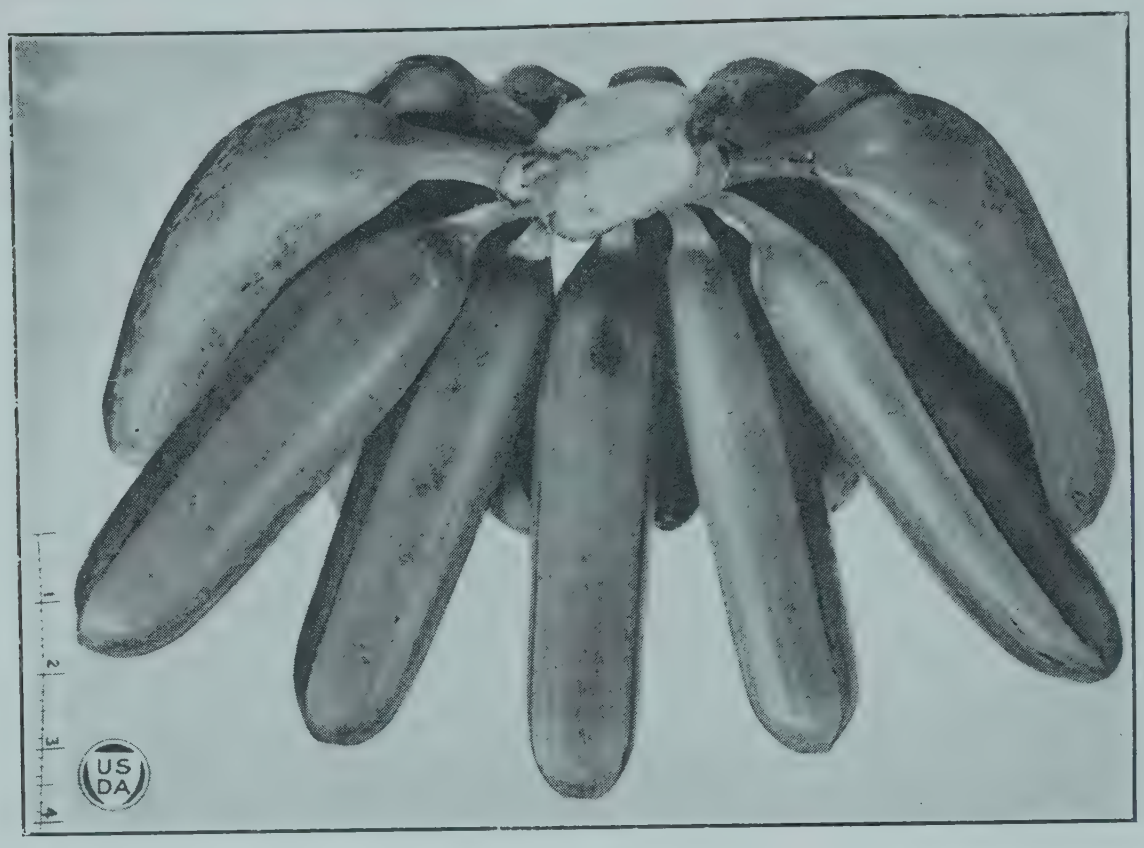


FIG. 1.—HAND OF KONA MAIAMAOLI BANANAS.

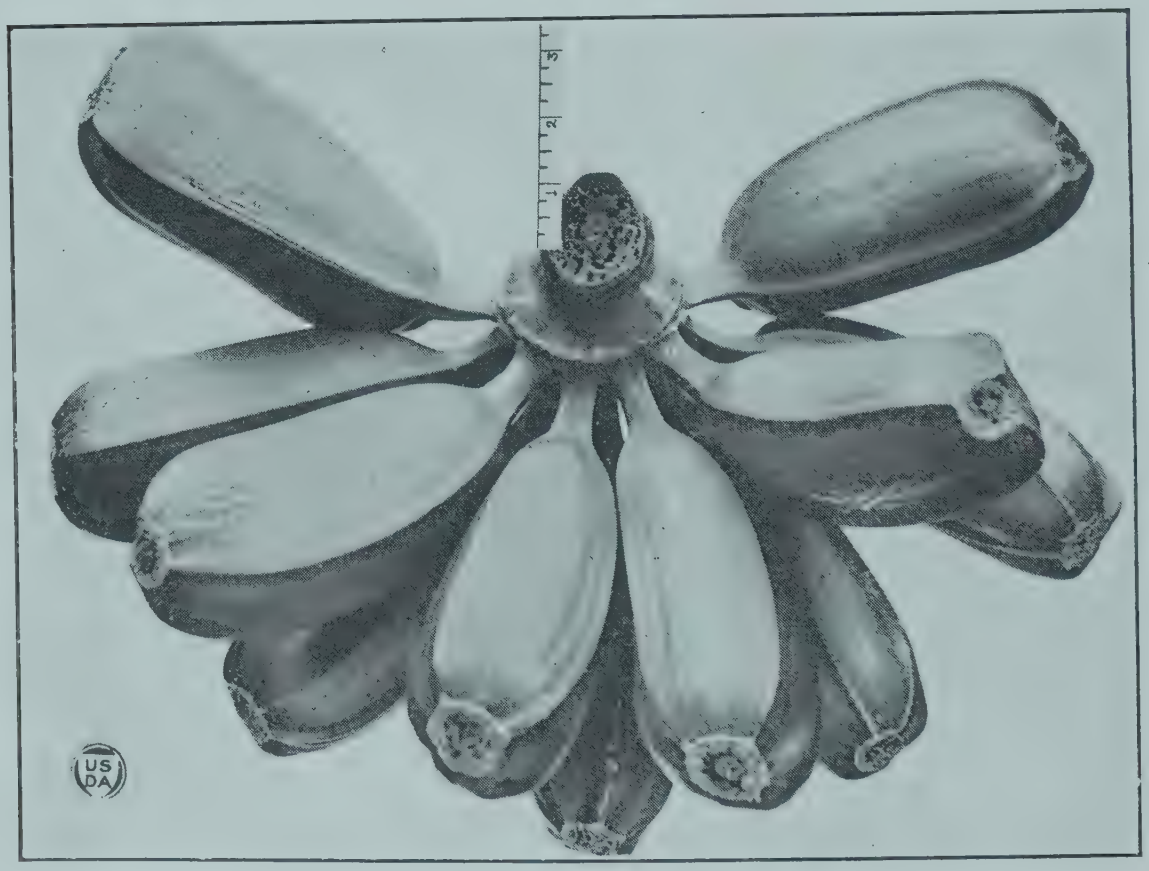


FIG. 2.—HAND OF POPOULU KAIO BANANAS.

FIG. 1.—PAPAYA NO. 4610. ROUND TYPE.

FIG. 2.—PAPAYA NO. 4618. LONG TYPE.

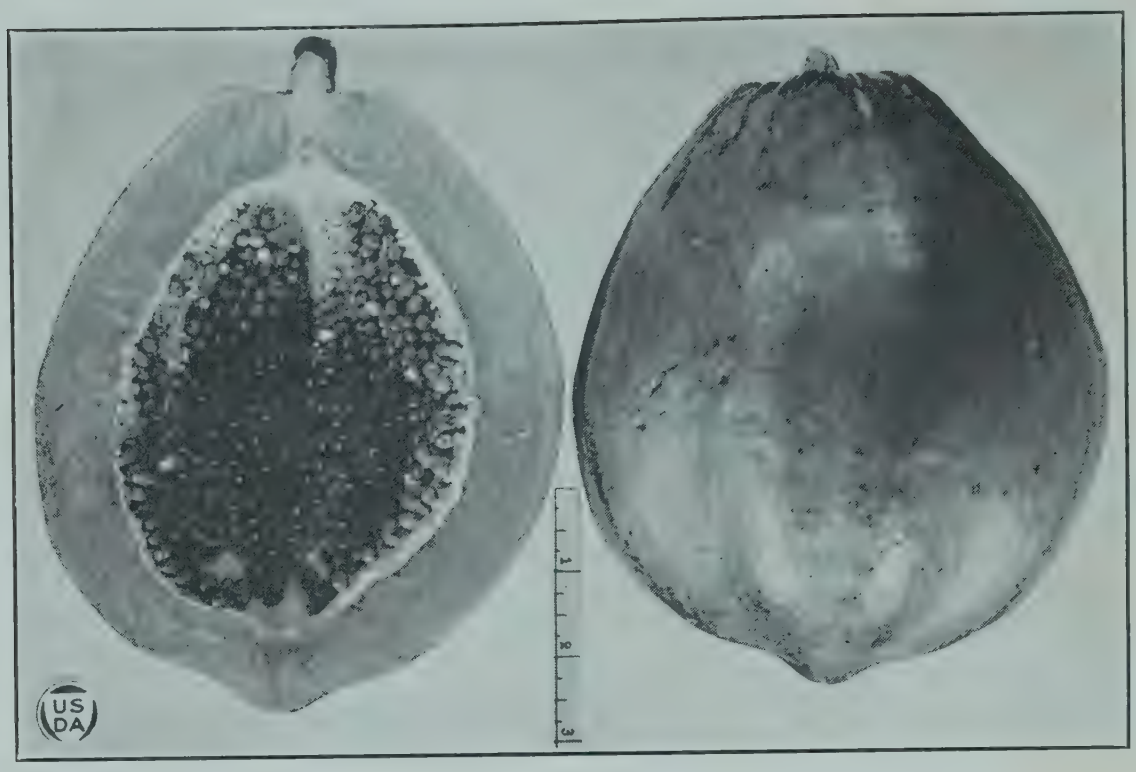


FIG. 1.—PAPAYA NO. 4610. FRUIT WEIGHS 4 POUNDS. COLOR, BRIGHT YELLOW.

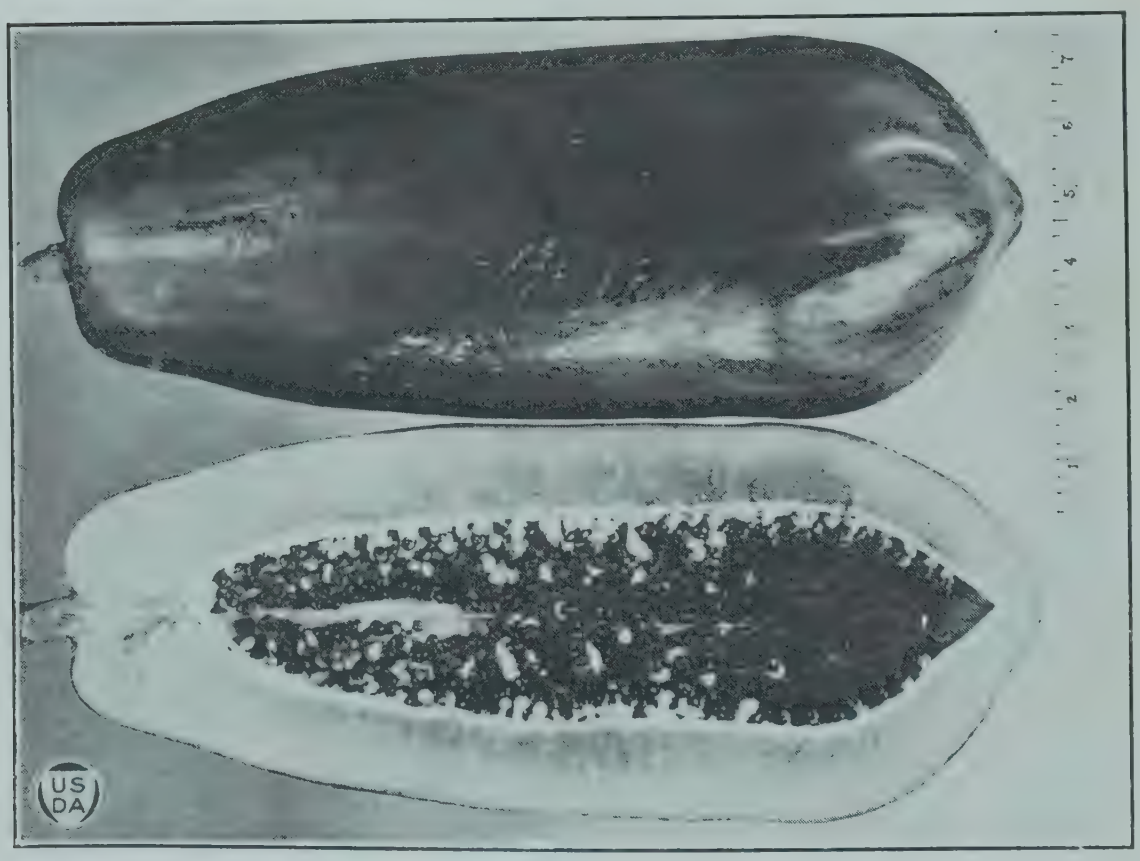


FIG. 2.—PAPAYA NO. 4618. FRUIT WEIGHS 6½ POUNDS. COLOR, YELLOW.

vation have helped to improve both yield and quality of the fruit and to reduce the ravages wrought by the mango weevil (*Cryptorhynchus mangiferæ*. Experiments show that the Pirie can be propagated by the bark-graft method, several hundred 1-year old seedlings having been successfully grafted with scions of this variety. Fourteen hundred seedling mangoes are being grown for grafting and budding to a number of good varieties which as yet are hardly known in the Territory. Local varieties springing from West Indian stock seem to do better and to be more prolific than Indian varieties, many of which are shy bearers and often fail to produce for several years in succession.

Victoria.—Among the seedlings developed from seed introduced into the islands from the West Indies during the 80's was a mango known as No. 9. Seed of this tree was planted on the date of the diamond jubilee of the late Queen Victoria of England, and the resulting tree was called Victoria. (Pl. VI, fig 2.) The tree is very prolific, producing sometimes as many as three crops a year. The fruits are usually produced singly on individual stems and differ in color from any other variety of mango growing in Hawaii, being red from the time they set and becoming brilliant scarlet on ripening. Like some other mangoes, the Victoria reproduces its quality of fruit fairly true to type on seedling trees. This variety may be propagated by grafting.

The fruit is of medium size, weighing about 9 ounces. Form, oblong, slightly S shaped, and at stem end somewhat necked; apex, broadly rounded with curve ending in a small blunt beak sometimes containing small hole-like depressions; color when ripe, brilliant vermilion shaded over yellow background, especially at the apex; surface, marked with small yellow dots, which become overcast where red is deepest; shoulder of fruit has delicate powdery bloom; skin, of medium thickness and peels off well; aroma, pleasant; ripe flesh, deep rich, yellow color and good texture; juice, sweet, acid, and of flavor of Pirie mango; seed, small, weighing three-quarters ounce; marketing qualities ranking among best varieties in Hawaii.

Wootten.—The Wootten is one of half a dozen trees which were inarched from the original tree growing in the yard of H. Wootten, on Makiki Street, Honolulu. Even before it is fully ripe, this variety has a beautiful coloring which is a very desirable marketing feature. In moderate temperatures the ripe fruit will remain in good condition for two weeks.

The fruit is medium to large; form, roundish, slightly flattened on the sides (no apex point evident); weight, about 10 ounces; color when ripe, a shade between orange yellow and yellow orange with tinges of pink and red at the stem end and pale yellow dots scattered over the surface; skin, medium thin, tough, and with fair peeling qualities; aroma, very pleasant; flesh, rich apricot yellow of very good texture; flavor, excellent; juice, sweet, acid; seed, medium to small for size of fruit.

Kalihi.—This hybrid is thought to be the result of a cross between a West Indian variety known as No. 5 and some other West Indian mango which grew in the Government nursery grounds on King Street, Honolulu. The trees are vigorous and prolific and produce fruit of fine quality when given cultivation.

The fruit is of medium size (Pl. V, fig. 2), weighing 11 ounces; form, oval with broad stem-end, which is depressed like that of the apple; apex end, broad, terminating in two rounded points, one of which is more prominent than the other; when ripe, the color is golden apricot splashed over the shoulders with blood-red spots and dotted over the whole surface with light yellow; skin, medium thickness, rather tough, peels off well; aroma, pleasant; ripe flesh, deep, rich yellow, of good texture; juice, sweet with subacid flavor; seed, medium to small, weighing three-fourths ounce. The fruit has good keeping qualities.

GRAPES.

The past year was favorable for the production of grapes, and the locally-grown fruit appeared constantly on the markets. The station is attempting to supplement the Isabella variety, the leading grape of Hawaii, with eight other varieties which are known to possess desirable qualities. These will be grafted on Isabella rootstocks for immediate production and cross-pollinated in an effort to secure improved table grapes suitable to island conditions. A number of vines of the Isabella variety have already fruited lightly. The tropical species known as *Vitis tiliæfolia* (S. P. I. No. 44060), introduced last year from the Bureau of Plant Industry, United States Department of Agriculture, has made good growth and is thought to have a future in connection with Hawaiian grape growing. Muscadine grapes, popular in the Southern States, are other introductions which are likely to become established.

The vineyard has been kept well cultivated and given irrigation when necessary, and the vines have been supported on a trellis of the Munson type. Sprayings with arsenate of lead have kept the Japanese beetle (*Adoretus umbrosus*) under control.

STRAWBERRIES.

New varieties of strawberries are being tested, and the growing of this fruit under screen in the home garden is being encouraged. It is thought that by inclosing a small strawberry bed in a specially constructed frame built after the manner of a hotbed and covered with heavy galvanized screening No. 26 (eight meshes to the inch) choice fruits can be grown under high culture without danger of its being destroyed by the Japanese beetle (*Adoretus umbrosus*). At the station an experimental frame of redwood 6 feet wide, 32 feet long, and 18 inches deep has been set in the soil to a depth of about 9 inches. The screens have been tacked to sashlike frames 4 by 6 feet and made to fit into the top of the frame resting on cleats. These are kept over the plants only at night, as the Japanese beetle is strictly nocturnal in flight and feeding. Inside the frame the varieties "New Carolina," Brandywine, and Progressive have been set in rows 1 foot apart in a bed of clean fresh soil with which well decomposed barnyard manure has been incorporated. Where the fruit is of such soft and quick growth and so hidden in the foliage as is the strawberry, a poisonous spray can not be safely used, and it is thought that the method outlined above will enable one to grow enough choice strawberries in the garden for family use at a reasonable cost.

TOMATOES.

The experiments in tomato improvement, which have for their object the development of varieties resisting attacks of the melon fly (*Bactrocera cucurbitæ*) and the Mediterranean fruit fly (*Ceratitis capitata*) and bearing fruit of increased size and improved quality, were continued.

The cross secured by hybridizing Earliana with the small, native tomato resulted in the production of a large tomato having fixed characters. It has the shape and toughness of skin of the wild tomato and some of the size and quality of Earliana. Seedlings of nearly 200 other variety hybrids, obtained in the same way, are being developed in order that it may be learned if they will continue to be reproduced true from seed.

Of a large number of interesting hybrids raised during the year, 53 have been selected for determination as to their ability to transmit their desirable qualities.

The results of the experiment are proving satisfactory, yields in general being large, and only few of the variety hybrids being susceptible to fly attacks.

OTHER FRUITS.

Root cuttings of the seedless breadfruit (*Artocarpus inscisa*) were propagated from surface roots in the fall. Six-inch cuttings which were laid horizontally in coral sand several inches below the surface made the best growth.

In September, 1921, a fine collection of seeds of the longan (*Euphoria longana*) was received from the Department of Productive Industries, Formosa. Eighty healthy seedlings have been grown from this seed, although it was in a sprouting condition when it arrived.

One thrifty mangosteen tree (*Garcinia mangostana*), sent from the United States Department of Agriculture, is growing at the station. Twenty-four trees of this species were received from Java during the year, but all were dead on arrival. Efforts will be continued to establish this valuable species in the Territory.

Root cuttings of a number of varieties of fig (*Ficus carica*) have been distributed, and two new varieties, a small, yellow fruited sort, and the Kadota, a white fig from California, are being propagated.

Seeds of the Pejubaye palm (*Guilielma utilis*) from Central America have been placed in sand for germination. The flesh about the seeds is the edible portion and is said to be of high food value. It is hoped that this useful tree can be established in the islands.

Seedlings have been grown from a number of seeds of the tree tomato (*Cyphomandra betacea*) which were received in the autumn of 1921.

Strawberry guavas (*Psidium cattleianum*) of an improved strain are being grown in the station orchard, and many young trees are being propagated for distribution.

NUTS.

COCONUTS.

Although all the coconut trees in the Territory are of the species *Cocos nucifera*, they have fixed characters which are peculiar to the

group of Pacific Islands whence it came. These characters reproduce even when the nuts are grown in Hawaii.

Tests of three materials were again made to determine the quickest and best way to secure germination of coconuts. Nuts were buried in rice hulls in the first test, in coarse black sand in the second test, and in coral beach sand in the third test, being placed in each case in pits 18 inches deep. Some nuts in each pit were buried whole, while others, from which a portion of the outer hull was removed at the base, were set with cut ends up just below the surface. Those set in rice hulls with cut ends up germinated best, sending up shoots in two and three months.

MACADAMIA.

Only a small crop of Macadamia nuts was obtained from the trees growing at the Tantalus substation. A number of these germinated, however, 50 young trees being set out at the substation and several hundred distributed throughout the Territory. The Macadamia will grow in the warmer localities near sea level, but it thrives better and makes more rapid growth in the cooler places.

PILI.

Several hundred Pili nuts (*Canarium ovatum*) were received from J. E. Higgins, of the College of Agriculture, Philippine Islands, during the year. Various tests were made to determine the best way to secure germination, but in each instance the percentage of germination was low.

PISTACHIO.

The pistachio is being propagated in the hope of getting it established in the Territory. Budding and grafting experiments will be undertaken as soon as the seedlings (*Pistacia vera* and *P. chinensis*) reach sufficient size. With the great variations of climate existing in the Hawaiian Islands it is thought that some locality can be found where this valuable nut will thrive.

REPORT OF THE AGRONOMY DIVISION.

By H. L. Chung.

ROOT CROPS.

CASSAVA.

Twenty-two varieties of cassava (*Manihot utilissima*) were grown in a light clay soil to determine their yielding values. The crop was harvested June 7, 1922, after a growing period of 15½ months. The four outstanding varieties for yield were São Pedro Preto, Tapicura, French No. 3, and Basioroa, which produced at the rate of 19.10, 13.23, 12.76, and 11.59 tons, respectively, per acre.

MANGEL WURZELS.

In December, 1921, a test of four varieties of mangel wurzels was undertaken to determine their yield when grown on a medium-clay

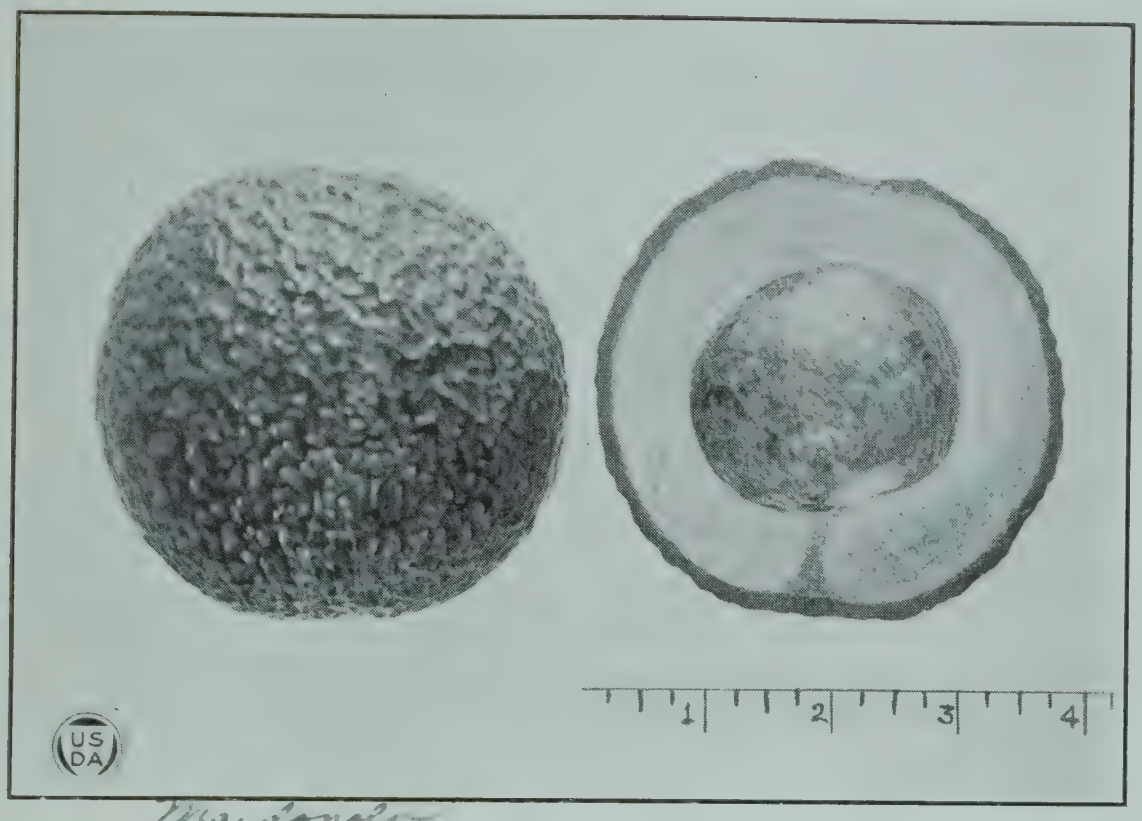


FIG. 1.—~~BEARDSLEE~~ AVOCADO. HARD-SHELLED FRUIT OF EXCELLENT QUALITY.

FIG. 2.—KALIHI MANGO. QUALITY EXCELLENT.

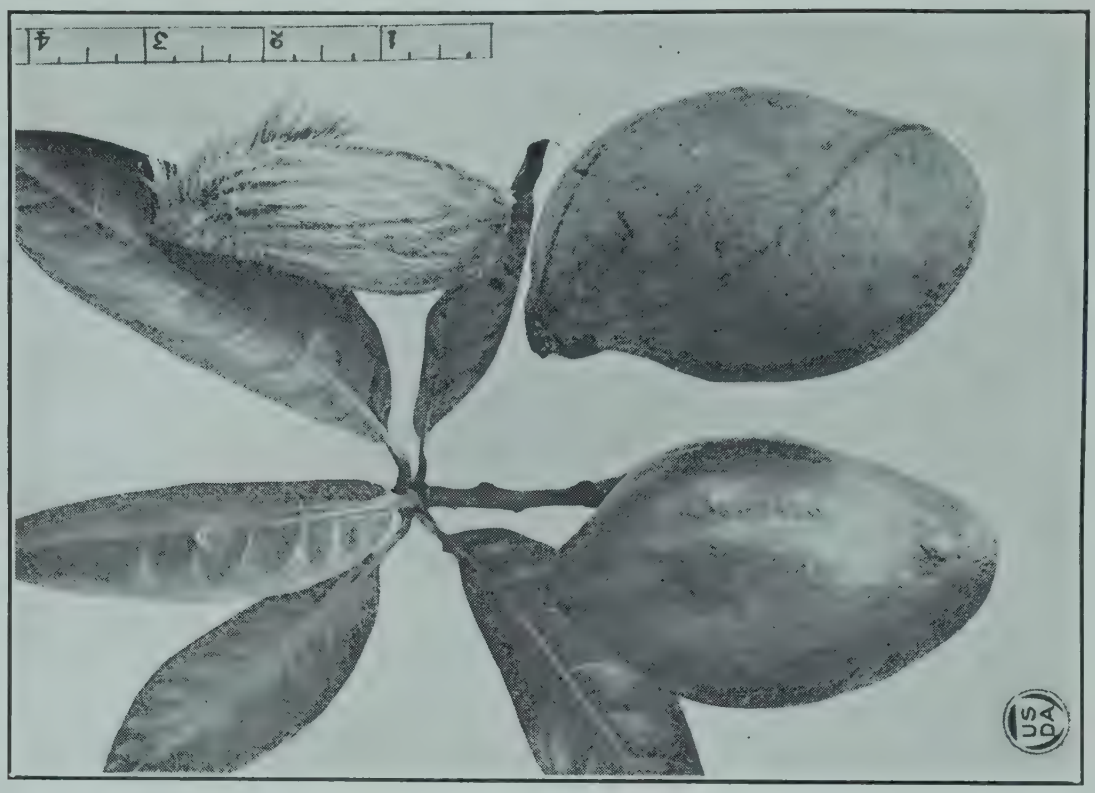


FIG. 2.—HAWAIIAN HYBRID MANGO (VICTORIA).

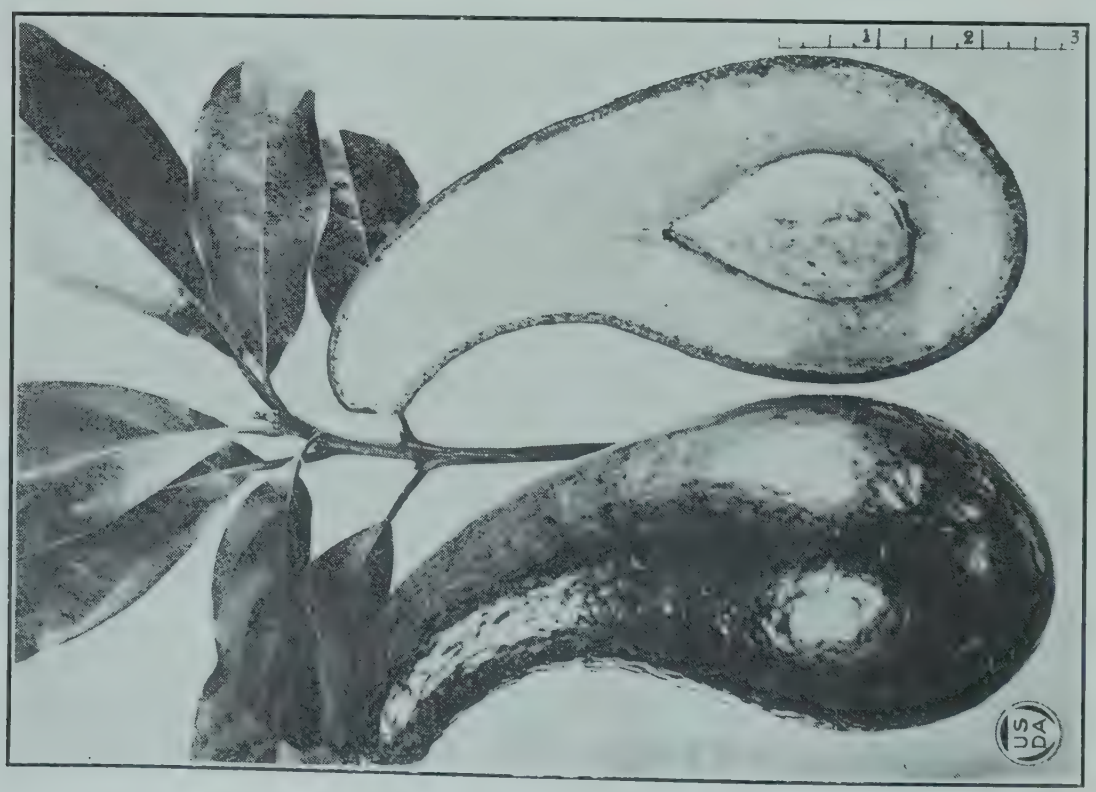


FIG. 1.—CASE AVOCADO.

soil with infrequent irrigation. The crop was given only three light irrigations and two cultivations from the time of planting to the last harvest.

Mammoth Long Red and Champion Yellow Globe made the highest yields, producing 26.6 and 27.7 tons, respectively, of roots in 4 months and 11 days after planting. These varieties were not only heavy yielders, but they also made luxuriant growth and were fairly resistant to drought.

CORN.

Corn investigations were again confined to breeding and the stabilization of a yellow strain of Guam corn. Careful selection of ears conforming in every character except color to the original white variety has resulted in the production of a large number of well-shaped ears showing uniformity of color and type of kernel.

In a hybridization experiment, undertaken in conjunction with the sweet corn investigations, a hybrid white Guam corn was used as the mother and the Henderson Sweet as the staminate parent. The former was planted in alternate rows with the latter and was detasseled at tasseling time. The hybrid cornstalks, representing 75 per cent sweet and 25 per cent Guam stock, are making vigorous growth and the kernels are in the dough stage (June 30, 1922).

FORAGE CROPS.

GRASSES.

Large distributions of cuttings of Napier grass (*Pennisetum purpureum*) and Merker grass (*P. merkeri*) were again made during the year to dairymen and farmers, and approximately 1½ acres were planted with these grasses for the production of cuttings for immediate delivery.

In conjunction with the improvement of forage crops, plantings were made of individual seedlings of Merker grass, giving indications of quality, heavy stooling, and rank growth.

In a comparative test of Napier grass, sugar cane, and kafir corn, Merker grass made the highest yields, producing 47.95 tons of green forage in two cuttings. The yield of Napier grass in the second cutting undoubtedly would have been higher had not Uba cane been grown close to it on one side and Merker grass on the other. The following table gives the results of the test:

Yield of eight forage crops which were planted May 7, 1921.

Crop.	Yield per acre.		Crop.	Yield per acre.	
	First cutting, Nov. 7, 1921.	Second cutting, Apr. 7, 1922.		First cutting, Nov. 7, 1921.	Second cutting, Apr. 7, 1922.
	Tons.	*Tons.*		*Tons.*	*Tons.*
Yellow Caledonia sugar cane	10.54	13.02	Uba sugar cane	23.17	23.82
Lahaina sugar cane	9.84	3.13	D-1135 sugar cane	13.94	12.35
Merker grass	23.52	24.43	109 sugar cane	2.11	3.39
Napier grass	19.16	6.44	Kafir corn	7.92	11.02

Natal redtop (*Tricholæna rosea*), Australian blue (*Andropogon sericeus*), Australian water grass (*Paspalum dilatatum*), Wilder grass (*Andropogon* sp.), and fuzzy top (*A. saccharoides*), which were planted in the demonstration plats in July, 1915, yielded in two cuttings, 7.7, 8.58, 6.43, 4.32, and 6.16 tons, respectively, of green forage. The relatively low yields were due to abnormal growth resulting from continuous cropping through seven years and consequent root binding. Data obtained from this protracted experiment show that about four years is the period of greatest usefulness of these grasses for pasture purposes.

A nonirrigated test was made of Tunis grass (*Andropogon sorghum*), Sudan grass (*Andropogon* sp.), Wonder Forage (*Andropogon* sp.), and *Panicum antidotale* from July 30, 1921, to April 3, 1922. Yields were about one-third of what could presumably be obtained with irrigation.

Panicum setosum and *P. complanatum*, planted July 7, 1921, yielded on October 28 at the rate of 50.9 and 6.7 tons, respectively, of green forage per acre. *P. setosum* is a rank growing grass and attains a height of 3 feet under normal conditions.

Exophorus unisetus and Guatemala grass (*Tripsacum laxum*), two new grasses tested during the year, have been found to be valuable additions as feed for livestock. The former is an erect grass and attains a height of 2½ feet to 4 feet. Its stems and leaves are of excellent quality. At the station this grass produced at the rate of 44.6 tons of green forage per acre, and large quantities of the seed were distributed to those interested in the improvement of Hawaiian pasture grasses.

Guatemala grass (Pl. VII, fig. 1) was cut for the first time July 26, 1921, when it yielded at the rate of 46.5 tons of green forage per acre. In an experiment made to determine whether this grass could be grown by cuttings, it was found that 60 per cent of the cuttings took root and developed into vigorous plants, 10 per cent developed but died later, and 30 per cent failed to develop.

SORGHUMS.

Four varieties of grain sorghum were tested for their green forage value during the year. An African variety, No. 309, produced 6.68 tons in 4½ months, while kafir, Amber cane, and Egyptian corn yielded 6, 8.9, and 4.9 tons, respectively, of green forage in three months.

KALE.

Jersey and Giant Marrow were planted to obtain data as to their yield and adaptability to poultry rations. Of the two varieties, Giant Marrow made the heavier yield, exceeding Jersey by 5.8 tons in the first harvest, 10 in the second, 5.1 in the third, and 8.9 in the last.

Many large plants of the Giant Marrow variety succumbed to the attacks of the larvæ of the melon fly.

LEGUMINOUS CROPS.

COWPEAS.

During the year station hybrid No. 1383, planted primarily for the production of seed, yielded approximately 200 pounds of clean seed from three plantings. Individual plants that were observed to be outstanding in rankness of growth, heaviness of foliage, and prolificacy, were selected for future work.

HUBAM CLOVER.

Hubam clover, planted on one-tenth acre for forage and seed production, yielded at the rate of 12.4 tons per acre on one-twentieth acre for a growing period of three months. The rest of the plat produced 22.5 pounds of hulled seed, or at the rate of 450 pounds per acre.

SUNN HEMP.

Work with sunn hemp (*Crotalaria juncea*) was confined to the selection of plants producing heavy foliage and many pods in the hope of improving the variety in these two characters.

DISTRIBUTION OF SEEDS AND CUTTINGS.

The number of seeds and cuttings distributed by the agronomy division during the year slightly exceeded that of the preceding year. For the 12 months ending June 30, 1922, the distributions were made in amounts as follows:

Seeds and cuttings distributed during the year ending June 30, 1922.

Crop.	Seeds.	Cuttings.	Crop.	Seeds.	Cuttings.
	Pounds.	*Number.*		*Pounds.*	*Number.*
Napier grass	4	55,412	Edible canna "tubers"	----------	12,504
Giant Bermuda grass	----------	2,136	Cassava	----------	2,416
Merker grass	4	2,822	Corn	195	----------
Natal redtop grass	8	24	Pigeon peas	109	----------
Sudan grass	----------	26	Peanuts	37	----------
Java grass	----------	12	Beans	30	----------
Kulthi grass	----------	8	Mungo beans	32	----------
Kikuya grass	----------	4	Kale	½	----------
Tunis grass	----------	2	Alfalfa	8	----------
Australian blue grass	1	----------	Hubam clover	6	----------
Wonder Forage	4	----------	Cotton seeds	2	----------
Molasses grass	1	----------	Kudzu (rooted cuttings)	----------	130
Buffalo grass [1]	----------	3,000	Sorghum	1	----------
Uba cane	----------	8,700	Sunflowers	1	----------
Honohono	----------	25	Field turnips	1	----------
Sweet potatoes	----------	8,408	Egyptian corn	1	----------

[1] Hawaiian variety.

POULTRY.

Judging from the nature and number of inquiries received, it is thought that poultry raisers are coming to realize more and more that intelligent culling is a deciding factor in profitable poultry production. A number of articles published by the agronomist in one of the local newspapers have undoubtedly stimulated this phase of the work.

Early in July, 1921, the station, working in cooperation with the Union Feed Co. (Ltd.), sent the writer to the mainland to study the poultry industry in the Haywood and Petaluma districts, California, and at the Agricultural College and Hanson Poultry Farm, Oregon. Two hundred and thirty yearling White Leghorn hens and cockerels and 31 Barred Plymouth Rock hens were purchased and taken to Honolulu by the writer. The White Leghorn hens selected were bred for high-egg production, having first-year trapnest records ranging from 250 to 298 eggs. The cockerels were immediate descendants of hens having a trapnest record of 304 to 307 eggs for their first year. The Barred Plymouth Rocks, purchased for patrons of the feed company, were closely related to a hen which had laid 324 eggs in 365 consecutive days at the California farm bureau egg-laying contest in Santa Cruz. All of the fowls were examined for characteristics indicating heavy egg-laying capacity and to make certain that they were free from disease, and a study was made of each fowl's pedigree. Shortly after their arrival in Honolulu, the Leghorns were graded and placed in four separate pens according to their egg records.

The agronomist also assisted in establishing a poultry plant at the United States Marine Corps Barracks, Pearl Harbor.

Sorehead (*Epithelioma contagiosum*) was very prevalent in some of the poultry yards during the year and caused heavy losses on Oahu in spite of the precautions taken. (Pl. VIII, figs. 1 and 2.) During the coming year it is hoped that sufficient time can be found to permit of the study of this disease relative to its prevention and cure.

Coccidiosis, a common poultry disease, appeared in two flocks in a new form, and the poultry succumbed without warning. On post-mortem examination the respiratory and digestive organs were found to be normal, except the cæca, which were distended and filled with coagulated blood. (Pl. VIII, fig. 3.) This disease was mentioned as an unidentified disease in last year's report.[1]

As soon as the disease is detected in the flock, crude catechu should be placed in the water given the birds to drink (one-third teaspoonful of the former to 1 gallon of the latter) for a period of one week, or until the birds regain their normal condition.[2]

REPORT OF THE CHEMICAL DIVISION.

By J. C. Ripperton.

COOPERATIVE FERTILIZER EXPERIMENTS.

BANANAS.

The great possibilities of banana growing on a commercial scale seem to warrant the undertaking of a series of rather intensive fertilizer experiments in connection with this crop. Tests are being made to determine the effect on the crop of applying fertilizers in single and fractional doses throughout the growing season, as well

[1] Hawaii Sta. Rpt. 1921, p. 35.
[2] U. S. Dept. Agr. Farmers' Bul. 957, Important poultry diseases, p. 23, 24.

FIG. 1.—GUATEMALA GRASS (TRIPSACUM LAXUM).

FIG. 2.—PIGEON PEAS. CENTER NOT FERTILIZED: BOTH SIDES RECEIVED FERTILIZER.

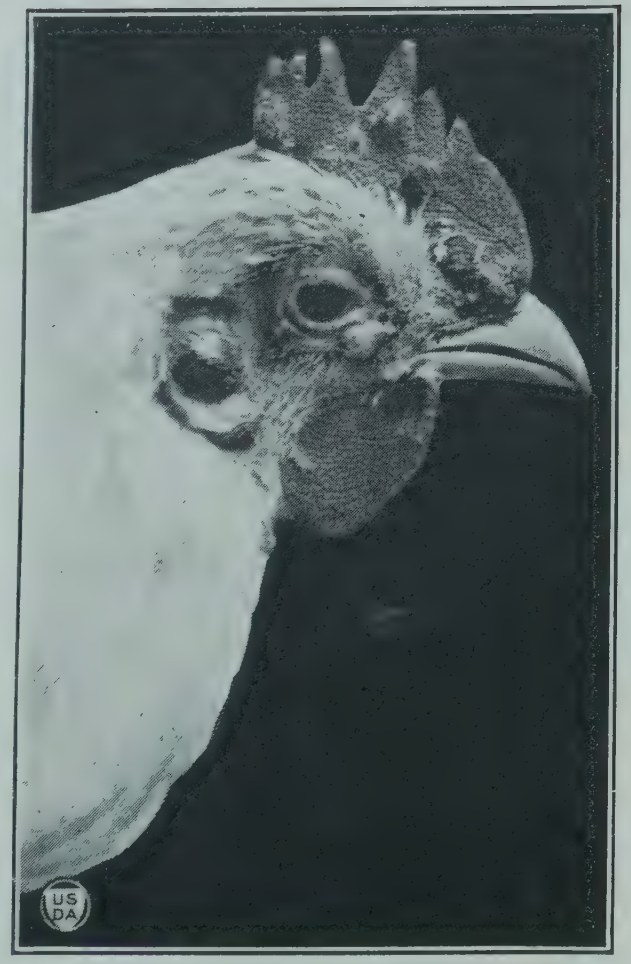


FIG. 1.—SOREHEAD, MILD FORM.

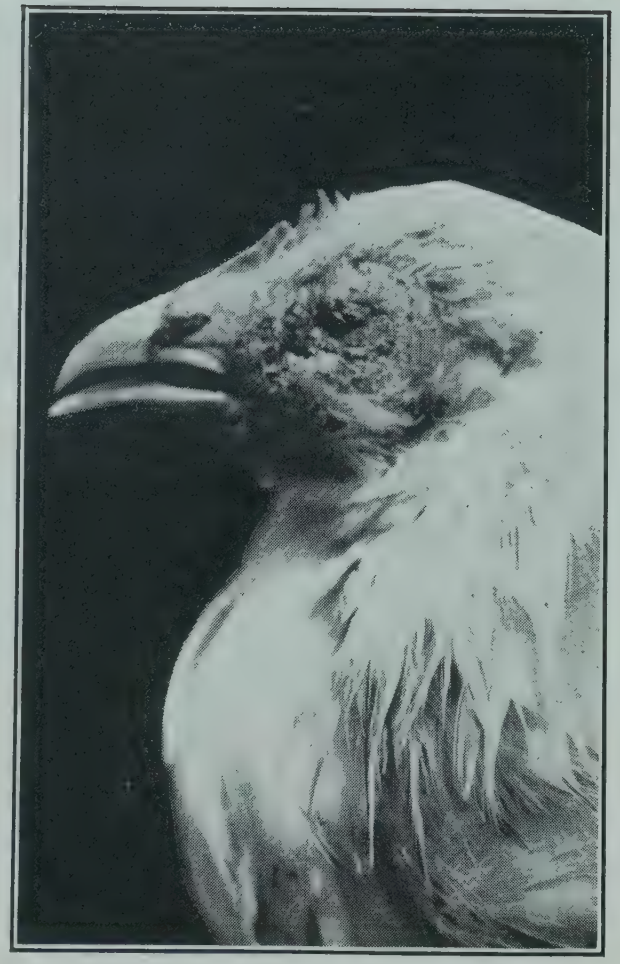


FIG. 2.—SOREHEAD, SEVERE.

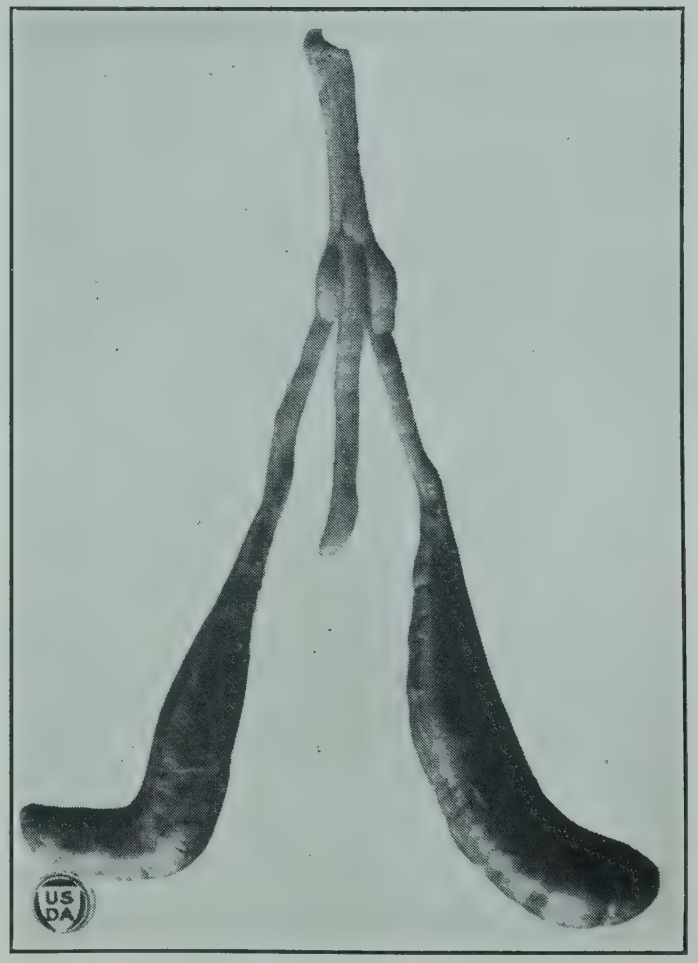


FIG. 3.—CÆCA OF PULLET DISTENDED WITH COAGULATED BLOOD, RESULT OF COCCIDIOSIS.

as the effect of leaching by irrigation waters on fertilizers applied in different parts of the ridge or furrow.

Three crops of bananas, harvested from the triangular fertilizer experiments,[3] failed to show any appreciable increase in weight or number of bunches due to fertilizer. Observation of the drainage ditches, opened to prevent water logging, showed a rapid downward percolation of the irrigation water, and the percolates were found to contain appreciable quantities of all the fertilizer salts applied.

Examination of the roots of a number of plants which were dug at different stages of maturity showed that the banana is essentially a surface feeder. Root hairs were found only on the upper whorl of roots except in case of plants two months of age or less. Some of the more vigorous plants had two whorls of feeding roots, but the lower roots were in a dormant or half-decayed condition. In Hawaii, where the banana is planted in a trench about 2 feet deep and the feeding roots extend outward almost horizontally into the ridges in consequence, it would seem that the fertilizer should be applied close to the surface.

In December, 1921, six half-acre plats were laid off and planted to bananas to determine the best method of applying fertilizer to the crop. In the first plat the total quantity of fertilizer was hoed in around the base of the plants immediately before irrigation; in the second plat a small trench was dug around the plants and the total quantity of fertilizer was hoed in the sides of the ridge and at about the level of the water during irrigation, so that capillary water only would reach the fertilizer; in the third plat one-sixth of the total quantity is being applied each month about the base of the plants and hoed in immediately before irrigation; and in the fourth plat one-sixth of the total quantity is being applied each month about the base of the plants immediately after the irrigation water sinks below the surface of the trench. The two remaining plats are serving as checks.

The same kind and quantity of fertilizer is being used in each plat. The fertilizer is made up chiefly of water-soluble salts, with nitrogen, phosphoric acid, and potash in the proportions of 6, 12, and 7 per cent, respectively, and it is being applied at the rate of 1,500 pounds per acre, which is equivalent to 1.5 pounds per plant.

Drainage ditches have been cut to permit of a comparison of the seepage water from the different plats, and it is expected that a series of percolation experiments will be carried on for the purpose of comparing the quantities of fertilizer leached out under the different methods of application.

PINEAPPLES.

In 1919 ten 0.1-acre plats at the New Era homestead farm were planted with 800 pineapple shoots each to determine the effect of fertilizer on pineapple wilt. The first application was made two weeks after planting, and the second, a supplementary one consisting of one-fourth the original quantity, was made on half of each fertilized plat one year later. Fertilizer was found to exert little or no effect on the crop, the last harvesting cycle of which was completed

[3] Hawaii Sta. Rpt. 1920, p. 34.

in August, 1922. The field was infested with pineapple wilt before the plant crop was harvested, and plats Nos. 1 and 2 were so severely damaged that less than half the plants produced matured fruit. The following table gives the yield of the plats as a whole:

Yield and weight of pineapple plant crop, grown with and without fertilizer, at Haiku.

Plat No.	Fertilizer treatment per plat.			Number of fruits harvested per plat.	Total weight of fruits per plat.	Average weight per fruit.
	Nitrogen mixture.[1]	Acid phosphate.	Potassium phosphate.			
	Pounds.	*Pounds.*	*Pounds.*		*Pounds.*	*Pounds.*
1	75			279	1,260	4.51
2	50	31		301	1,457	4.84
2 (check) [2]				455	2,361	5.18
3	50		8.3	527	2,699	5.12
4	25	58.3		484	2,536	5.24
4 (check) [2]				533	2,846	5.34
5	25	31	8.3	546	2,804	5.13
6	25		16.6	608	3,147	5.17
6 (check) [2]				632	3,245	5.13
7		87.5		554	3,034	5.47
8		62	8.3	524	2,842	5.42
8 (check) [2]				530	2,665	5.02
9		31	16.6	537	2,898	5.39
10			25	514	2,875	5.59

[1] Ammonium sulphate, 45 per cent, and sodium nitrate, 55 per cent. [2] No fertilizer.

In considering the results it should be borne in mind that the field became severely infected with pineapple wilt, and, as is shown by the high average weight of the fruit produced on the check plats, the soil was exceptionally fertile and would not therefore respond to fertilizer treatment as would poorer soil. The experiment shows that neither the fertilizers used nor the vigorous growth made by the crop was able to ward off the wilt. The experiment was discontinued with the final harvest.

UPLAND SUGAR CANE.

In order to determine the effect of fertilizer on yield, Yellow Caledonia upland sugar cane was planted October, 1919, at Haiku on 26 plats, each one-tenth of an acre in size, which had previously been cropped with pineapples. Nonirrigated sugar cane, which has the same cycle of productive growth as the pineapple and yields as high as 6 tons of sugar per acre, gives promise as a profitable crop for rotating with pineapples in certain sections. Three rows were made to a plat. The first fertilizer was applied October 15, 1919, and about a month later two rows of each fertilized plat were given a supplementary application equaling one-fourth the quantity applied the first time. The year following planting was exceptionally dry and the cane made very little growth. The second year, however, had normal rainfall and the growth was rapid, but harvesting was delayed until the spring of 1922. Since the crop showed no effect of the supplementary application, only the yield of the plats as a whole are given in the following table:

Yield of upland sugar cane at Haiku.

Plat No.	Fertilizer treatment per plat.			Yield per plat.		Calculated increase per acre, due to fertilizers.	
	Nitrogen mixture.[1]	Acid phosphate.	Potassium sulphate.	Cane.	Sugar.	Cane.	Sugar.
	Pounds.	*Pounds.*	*Pounds.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*
1[2]	75			2.27	0.289	4.50	0.573
2	60	20		2.75	.350	.30	.038
3 (check)[3]				2.72	.346		
4	60		5	2.81	.358	.86	.110
5	45	40		3.19	.407	4.62	.589
6	45	20		3.11	.396	3.78	.482
7	45		10	3.17	.404	4.34	.553
8 (check)[3]				2.74	.349		
9	30	60		3.01	.384	3.58	.456
10	30	40	5	2.84	.362	2.76	.352
11	30	20	10	3.01	.384	5.34	.680
12	30		15	2.74	.349	3.52	.448
13 (check)[3]				2.30	.293		
14	15	80		2.78	.354	3.98	.507
15	15	60	5	2.84	.362	3.76	.479
16	15	40	10	2.74	.349	1.94	.247
17	15	20	15	2.90	.369	2.72	.345
18 (check)[3]				2.71	.345		
19	15		20	3.08	.393	3.68	.469
20		100		3.05	.389	3.36	.428
21		80	5	3.44	.438	7.24	.922
22		60	10	3.33	.425	6.12	.780
23 (check)[3]				2.72	.346		
24		40	15	2.97	.378	2.50	.318
25		20	20	3.02	.385	3.00	.382
26[2]			25	2.76	.352	.40	.051

[1] Ammonium sulphate, 45 per cent, and sodium nitrate, 55 per cent.
[2] Damaged by cattle.
[3] No fertilizer.

The above table shows that distinct increases resulted from the fertilizer treatment, but there appears to be no relation between the amount of increase and the composition of the fertilizer applied. Phosphoric acid was the only single fertilizer giving an appreciable increase, and plats 21 and 22, which received this element in fairly large quantities, made the highest yields.

FERTILITY-ROTATION EXPERIMENT.

During the year the pigeon-pea crop was plowed under and both the pineapple and sugar cane plant crops were harvested. The unusually severe drought of 1919–20 caused these two crops to make small yields, and very little effect could be attributed to the fertilizer treatments. The pineapple plat receiving nitrogen mixture (sodium nitrate, 55 per cent, and ammonium sulphate, 45 per cent) at the rate of 400 pounds per acre was very perceptibly greener and sturdier than the adjacent plats. The fruit averaged one-half pound heavier than that from the check plat. The plat receiving nitrogen mixture and potassium sulphate at the rate of 400 and 200 pounds, respectively, per acre responded equally well. This experiment will be continued.

PRESERVATION OF HAWAIIAN FRUITS.

During the year an intensive study was made of the guava, grape, and roselle for the purpose of developing a systematic procedure for making jelly from any kind of tropical fruit containing pectin and

acid. The results of this investigation have been submitted for publication.[4] Cooperative work with a local company with a view to standardizing the juices used for jelly making was continued, and the methods developed in the foregoing study are proving practicable for jelly making on a commercial scale.

Additional products having especial commercial possibilities are dehydrated mango, from which an excellent candied fruit can be made; dehydrated papaya, which mixed with lemon makes a cheap but excellent jam; and dehydrated guava, from which jelly can be made.

MINERAL CONSTITUENTS OF HAWAIIAN VEGETABLES.

Certain classes of people in Hawaii are of the opinion that locally grown vegetables are lacking in lime, iron, and other essential mineral constituents, and that they are not, for that reason, as good as the imported vegetables. Results of an experiment, conducted to determine the mineral constituents of the more common locally grown vegetables, show that Hawaiian-grown vegetables are as high in mineral content as the imported. The following table gives the results of a preliminary test made to determine the mineral constituents of spinach and cabbage, which are commonly found on the markets of the mainland, as compared with those of the locally grown cabbage and Chinese spinach:

Comparison of mineral constituents of Hawaiian and mainland grown spinach and cabbage.

[Calculated as percentages of dry material.]

Vegetable.	Where grown.	Total ash.	Phosphoric acid (P_2O_5).	Ferric oxid (Fe_2O_3)	Potash (K_2O).	Lime (CaO).
Spinach (canned)	California	20.82	0.97	0.048	3.92	0.90
Spinach (dehydrated)	Oregon	22.16	1.90	.075	7.65	.82
Spinach (fresh)	Hawaii (Honolulu)	23.36	1.97	.102	7.11	2.85
Do	do	17.60				2.92
Do	do	21.34				2.82
Do.[1]	Virginia	20.68	1.33	.090	8.60	1.14
Cabbage (fresh)[2]	Ohio	7.19	.59		3.01	.83
Do	Hawaii (Oahu)	9.13	.98	.045	3.20	.93

[1] Jour. Agr. Research, v. 16, No. 1, p. 17.

[2] Ohio Agr. Expt. Sta. Bul. 255, p. 226.

Some of the variations in results may be due to lack of uniformity in the variety of vegetable tested, and in the case of the California sample loss of some of the mineral constituents may have occurred during the process of canning. The results show, however, that locally grown spinach and cabbage are equal, if not superior, to the commonly imported brands in the important mineral constituents.

Carrots, beets, cabbages, spinach, string beans, and peas have been planted in two widely separate localities on the mainland (Virginia and Washington State), and also in two localities on Oahu in order that a comparison may be made of their nutritive constitutents. All four series are to be harvested at the same stage of maturity and

[4] Hawaii Sta. Bul. 47, Application of the principles of jelly making to Hawaiian fruits.

then dried. Any difference in composition of each crop will doubtless be due to the soil and climatic conditions prevailing at each place, since the seed stock is the same.

HAWAIIAN STARCHES.

TREE FERN.

Three experimental plats have been established at different altitudes along the Volcano Road to determine the feasibility of replanting the tree fern for starch production on cut-over areas. At the end of 9 months 85 per cent of the plantings were growing, including crowns, and large and small lateral shoots of the several varieties.

Rate of growth of the tree fern has been learned by measuring the vertical distance between the frond pits on the same "spiral." A complete circle of fronds averaging five in number develops at one time and each frond of the circle represents one of the spirals on the trunk. Since probably only one circle of fronds is developed in a year, it is concluded that the annual vertical growth is about 4 inches.

EDIBLE CANNA.

Complete chemical analyses are being made each month of samples of edible canna to determine at what stage of growth the tubers will yield the maximum amount of starch, and an experiment is being conducted in cooperation with a company in Hilo to study the commercial possibilities of the crop. In June, 1922, edible canna was planted in 36 plats, each one-tenth acre in size, to determine its fertilizer requirements. The plats are 18 miles from Hilo along the Volcano Road, where the elevation is 2,000 feet, and the soil is somewhat thin, being underlain by undecomposed lava at a depth of a few inches to several feet. The first application of fertilizer will be made in July, 1922, and the results of the experiment reported upon next year.

Small plats of canna have been planted along the Volcano Road at elevations varying from 300 to 3,500 feet to learn the highest altitude in which the crop can be successfully raised. Monthly harvests are to be made of 10 hills on each plat to ascertain the rate of growth and maximum yield.

EFFECT ON CROPS OF BRACKISH IRRIGATION WATER.

Studies are being continued to determine the tolerance of various crops to brackish irrigation water. Three crops, alfalfa, rice, and Napier grass were planted in lysimeters, and after germinating and reaching a height of 2 inches in fresh water were given measured quantities of water containing varying amounts of sodium chlorid. The percolates were collected and the sodium determined. Alfalfa was found to withstand a greater percentage of salt when once well established than when it was in the seedling stage.

Many soils which have been watered continuously with salty irrigation water are showing evidence of considerable accumulation of salt. It is planned to repeat the above-mentioned experiment with a second crop to learn what this cumulative effect in the soil is. It

is also planned to visit all the important irrigated sections of the islands to learn the salt content of the well water used in each district, the salt accumulation in the soil, and the kind and condition of crops being grown. The results should furnish a valuable guide for each district as to the limit of salt in the water, the danger of its accumulation, and the salt tolerance of all the common crops.

REPORT OF EXTENSION AND DEMONSTRATION WORK ON THE ISLAND OF HAWAII.

By R. A. Goff.

SOILING CROPS FOR PLANTATIONS.

The majority of the plantation owners, having enlarged their dairies or established new ones for the purpose of providing their laborers with milk at cost, are interested in the question of feeds for dairy stock. Pigeon peas and Napier grass are apparently the two crops best adapted to this purpose, as they produce a number of ratoon crops before it is necessary to replant, withstand the heavy rains and occasional dry periods of the district equally well, and form a balanced ration with the addition of very little imported milled feeds. Distribution of seeds and cuttings of these crops has been made to various plantations, and every assistance has been given to those who are interested in planting.

SCHOOL AND HOME GARDEN WORK.

The extension agent acted as one of the judges in the Star-Bulletin school-garden contest in the districts of Kau, Kona, Waiamea, and Kohala, and in the smaller contests in the outlying districts of Hamakua and Puna. Three visits were made to each of 11 schools and 35 home gardens, the pupils accompanying the judges in each instance to the gardens to discuss insect pests, seed varieties, and fertilizers.

COOPERATION WITH BOY SCOUTS.

The extension agent has served as scout commissioner for the island since January, 1922. He has given a number of talks on natural history and gardening to the scouts at schools in the country and has taken the boys on hikes to various plantations and homesteads to instruct them in the use of farming implements.

WORK IN WAIAMEA DISTRICT.

In 1922, A. W. Carter, manager of the Parker ranch, set aside 16 acres as a demonstration plat for the raising of crops of benefit either to the ranch or to local homesteaders. The work is carried on under the direction of the extension agent, and the labor, farming implements, and work animals are furnished by the ranch. Over 50 varieties of seed were supplied by H. L. Chung, of the central station, and as many more were ordered from the States, Australia, and England by Mr. Carter. Most of the plantings have

been failures so far, due to the elevation (2,700 feet) and to the prevailing heavy winds of the district. Corn (three varieties), potatoes (two varieties), forage crops (eight varieties), beets (four varieties), grasses (seven varieties), and clover (two varieties) are apparently doing well, however. Many homesteaders are interested in the project and are making inquiries about the different varieties being tried.

WORK IN KOHALA DISTRICT.

Through the efforts of the extension agent, many seedling trees were obtained from the local nursery of the Board of Agriculture and Forestry for planting as windbreaks in the district of Kohala. Fruit trees were pruned, plantings distributed, and talks given to groups of interested homesteaders who have considerable area in pineapples.

WORK IN KONA AND KAU DISTRICTS.

During the year the extension agent ordered seed of brome and rye grasses, pigeon peas, and bur and sweet clover, which have done well elsewhere on Hawaii, for the owners of cattle ranches in the districts of Kona and Kau, where they are being tried for the first time. The crops have been planted in plats and broadcasted in pastures and should help to improve the land.

A dairy is planned in connection with the junior high school at Kealekekua, Kona, and purebred Holstein cattle have been promised by the Parker ranch when an additional 10 acres, adjoining the school property, is secured and the buildings are up. Seeds and cuttings of Peruvian and Grimm alfalfa, Napier grass, Waiamea white corn, Boone County White and Reid's Yellow Dent corn, pigeon peas, and *Paspalum dilatatum* have already been planted so as to provide some of the necessary feed for the cattle when they arrive. The boys of the school are raising the crops. Two ranchers of the district have already asked for seed of some of the crops which they have seen growing at the school.

GLENWOOD SUBSTATION AND DEMONSTRATION FARM.

The number of livestock is being rapidly increased in the Glenwood district, and animal raising is being depended upon for profitable returns owing to the difficulty of raising marketable crops. Forage crops which can be fed green are being grown, and Australian water grass and bur clover are being broadcasted to improve the pastures rapidly.

The dairy herd of the substation consists of 14 milk cows and 20 heifers and calves, which will be headed by a recently purchased purebred Holstein bull calf. In addition to this herd there are on hand 1 purebred Berkshire boar, 3 Berkshire sows, and a poultry flock, which is increasing at the rate of 100 laying hens a year.

The farm was established for the purpose of demonstrating that 50 acres of well-stocked land in the Glenwood district can be made to support a family. It has done good work, and in the opinion of X. L. Helbush, the collaborator in immediate charge, the projects should be brought to a satisfactory close during the coming year.

FRUIT TREE NURSERY.

In 1921, 2,000 avocado and 500 mango seedlings were planted for the purpose of budding and grafting some of the better varieties of these trees for free distribution. With the assistance of C. E. Vaile, agriculturist at the Hilo Boarding School, 650 of the avocado seedlings were budded with wood from winter bearing trees in Hilo, and about 400 more are being budded with material sent from the central station. The remaining avocado and all of the mango seedlings will be worked over this summer as they become of sufficient size. Papaya seedlings have been distributed and some 800 rough lemon and shaddock seed planted for stock for grapefruit and orange budding.

REPORT OF HOME DEMONSTRATION ACTIVITIES.

By Mrs. N. A. Russell.

During the summer and autumn of 1921 the home economics demonstrator, acting in cooperation with the social welfare bureau, made weekly visits to one of the local pineapple canneries, where she instructed groups of 22 to 75 Japanese, Chinese, Philippine, Portuguese, and Hawaiian women in the growing and use of fruits and vegetables. At least one practical recipe was worked out for each fruit or vegetable, and samples of the prepared dishes were given to those attending.

In cooperation with the housewives' league, she gave an hour's talk each month, followed by demonstrations, on the utilization of meats, vegetables, and fruits of the Hawaiian Islands. This group of women is largely of American parentage, and as many as 100 attended some of the meetings.

Demonstrations of the making of papaya and tomato products were given in cooperation with the educational committee of Wahiawa for the benefit of the boys and girls of the seventh and eighth grades. Fully 48 children and 7 adults attended each meeting.

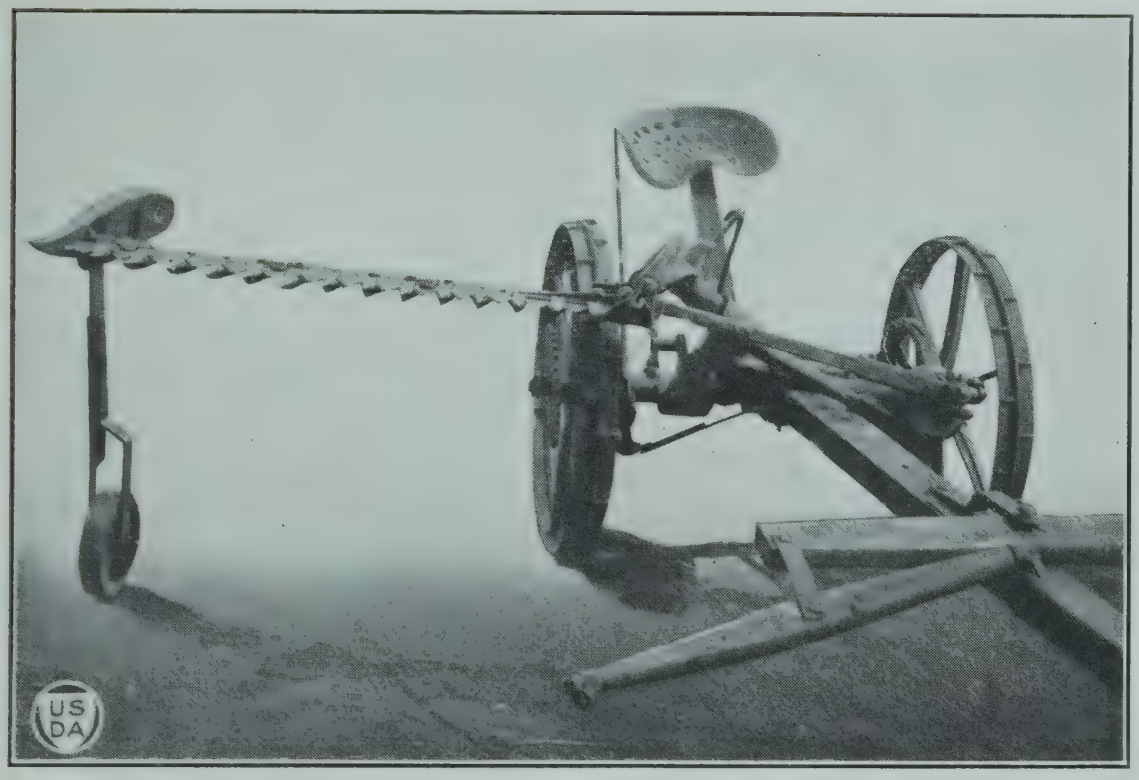
HAIKU SUBSTATION AND DEMONSTRATION FARM.

By F. G. Krauss.

PIGEON PEAS.

Probably no other crop in Hawaii lends itself so readily to a large variety of conditions as does the pigeon pea. Fully 10,000 acres are under cultivation in Hawaii, and fully 25 tons of the seed, or enough to plant 5,000 acres, was distributed during the year, large quantities being sent to Guam, Australia, New Zealand, East Africa, California, and Florida. The adaptability of the crop to very sandy and somewhat saline beach lands has been fully demonstrated.

Under average field conditions pigeon peas as pasturage may be expected to carry from one to two and one-half head of cattle per



MOWER ADAPTED FOR CUTTING PIGEON PEA FORAGE.

acre for two 100-day periods, or during the normal seeding stage of the crop. An acre of pigeon peas under good average conditions should produce from 300 to 1,000 pounds of prime beef per annum. The same lands in ordinary grass pasture frequently carry less than one head for 2½ to 5 acres.

The following table gives the relative yield per acre of ordinary field crops of pigeon peas with and without irrigation:

Comparative yields per acre of pigeon peas, grown with and without irrigation.

[Seven months after planting.]

Parts of individual plant.	Nonirrigated field.	Irrigated field.
	Pounds.	*Pounds.*
Whole plant (including roots)	32,500	82,900
Forage	11,400	30,560
Seed (shelled)	1,120	1,623

These data were compiled from results obtained by a sugar company in Maui and from the University Farm, Manoa Valley, Oahu. The Maui soil is very sandy and somewhat saline. The Oahu soil is a heavy, gravelly loam. Both soils are extremely dry in summer and produce very few crops without irrigation. The above table shows that under the conditions noted greatly increased crop yields may be expected from irrigation.

PIGEON-PEA FERTILIZER EXPERIMENT.

In a fertilizer experiment, conducted at Pupukea on raw uplands failing to produce more than 2 or 3 tons of pineapples per acre and only very few other crops, a fertilized plat yielded 13.07 tons of green forage, compared with 2.61 tons produced by an unfertilized plat. (Pl. VII, fig. 2.) The results show that under the unusual conditions presented in this case fertilization is essential and profitable for the production of even moderate yields. Phosphatic fertilizer was applied at the rate of 500 pounds per acre in the drill at the time of planting at a cost of about $12 per acre.

IMPROVED EQUIPMENT FOR THE CROP.

Judging by the new and improved machinery now being devised by various pigeon-pea growers, it would seem that a well-designed pigeon-pea equipment should be available for use within the year. Through the ingenuity of E. Falk, farm superintendent for Dr. W. D. Baldwin, Haiku, Maui, an ordinary mowing machine has been adapted to cut pigeon-pea forage. (Pl. IX.) The cutting bar of the mower is elevated to cut at a height of about 30 inches, the tongue or pole being moved to the center of the frame, the forepart of which is lifted at the same time to the desired height. This is done automatically by placing the pole under instead of over the frame. The pole is held firmly in place by a strong supplementary iron clamp. A seeder having fertilizer attachment has been devised by L. E. Arnold to facilitate the work of planting large areas of pigeon peas.

PINEAPPLES.

Pineapple growers are giving every attention to improved cultural methods and to careful breeding work through bud selection. Far better tillage is being practiced than formerly, and green manuring crops are being plowed under with excellent results over widely different conditions. It is thought that pineapples can be made to follow sugar cane satisfactorily. At Haiku a 5-acre field in which pineapples are following cassava is doing well.

Substantial advances are being made in the use of commercial chemical fertilizers, 500 to 1,000 pounds of which are being applied in the drill at the time of planting, followed by supplementary doses of ammonium sulphate throughout the growth of the crop. These later applications may be applied as a spray or top or side dressing. Spraying with iron-sulphate solutions with or without ammonium sulphate has become a common practice on manganiferous soils. Possibly one of the most radical and far-reaching practices inaugurated in connection with pineapple culture in recent years is the introduction of the paper mulch. It is as yet too early to predict its final outcome.

HALEAKALA SUBSTATION AND DEMONSTRATION FARM.

By J. F. O'Brien.[5]

MISCELLANEOUS PLANTINGS.

During the year about 30 different crops were tested either in small plats under different quantities of fertilizer or under field conditions. Ten acres each of cowpeas and soy beans and 1 acre each of 10 different varieties of corn were planted for trial. The low night temperature at this elevation (1,800 feet) is not conducive to the best production of corn, and the crop was forced to grow with less than 2 inches of rainfall a month. The most successful field crops are those thriving during the cool rainy season from September to March and ripening during the hot, dry season of June and July.

The pigeon pea has proved its adaptability to conditions at the Haleakala demonstration farm, and its seed has assisted materially in furnishing feed for turkeys.

Seed of the purple vetch, inoculated and planted November 12 on a freshly cleared plat, made excellent growth, yielding 10 tons of green forage per acre within 100 days after planting. The second growth was nearly as heavy as the first and required about 200 days in which to mature its seed.

Emmer, planted in December, 1921, survived the severe rain and wind storm that practically destroyed oats and other crops. It began heading 120 days after planting. Some acclimatization work will have to be done with this crop, but its showing in comparison with other grain crops is such as to make it take rank with the promising crops of the locality.

The Bellingham pea made excellent growth under field conditions, even though only lightly fertilized with equal parts of re-

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[5] Temporarily employed as collaborator.

verted and superphosphate. The crop matures in about 120 days. Plantings made in January gave the best results. By planting early in October and again in January, however, it is possible to obtain two crops from the same land within 12 months. These peas will not thrive in warm weather. They should be planted fairly thick, either broadcast or in rows from 2 to 3½ feet apart, and be kept well cultivated.

HALEAKALA TOMATO.

The Haleakala tomato, which has been especially selected and bred for its fly-resistant qualities, has for a number of years shown itself adapted to conditions on Maui. It shows a tendency to produce its fruit in clusters, bearing five and six rather large fruits at almost the same height on the stem.

MISCELLANEOUS FRUITS.

Carolina strawberries, planted October, 1921, made excellent growth, the berries being large and plentiful. In ordinary seasons planting should be made in September immediately after the heavy rains. The ground should be pulverized as deeply as possible, and enriched with stable manure (20 tons per acre). The plants should be kept cultivated.

It is thought that the wild variety of poha can be made to grow under cultivation with a corresponding increase in yield.

LIVESTOCK.

The station is maintaining a small herd of goats headed by a registered Toggenburg buck, Gretel's Son No. 1554. The entire local area is typical grazing land, and there is every indication that dairying can be successfully carried on. It is also felt that poultry and hog production may be made supplemental lines of work to other activities helping to make successful a number of self-supporting small farms in the vicinity.

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HAWAII AGRICULTURAL EXPERIMENT STATION
HONOLULU, HAWAII
Under the supervision of the
UNITED STATES DEPARTMENT OF AGRICULTURE

Washington, D. C. July, 1924

REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION, 1923.

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SUMMARY OF INVESTIGATIONS.

By J. M. WESTGATE, *Agronomist in Charge.*

During the fiscal year 1923 the station continued its policy of fostering the development of diversified agricultural industries in the islands. Special attention was given to the production of staple food supplies which, in either the raw or manufactured state, can be exported at a profit during normal times or used to feed the local population in the event of calamity befalling the sugar and pineapple industries or of interruption of shipping.

The scientific work of the station consisted in solving problems arising in connection with the development of agricultural industries. Perhaps the most important problem solved is that of overcoming chlorosis of pineapples growing on manganiferous soils by spraying the leaves with a solution of iron sulphate. As a result of this one discovery the value of the output of pineapples is estimated to have been increased to date by $10,000,000.

In the horticultural division leading varieties of tropical fruits, including bananas, avocados, papayas, mangoes, and breadfruits are being improved by breeding work, and successful propagation methods are being worked out in connection with such fruits as fail to come true to seed. Results worthy of mention are being secured with varietal selections of figs, mulberries, strawberries, and the poha or husk tomato. During the year approximately 25,000 plants and packages of seed of improved varieties were distributed to cooperators throughout the islands.

Agronomic work was directed principally toward the development of coarse forage grasses which will readily withstand continuous

cutting. Such grasses are needed in Hawaii, where there is no cessation in the growing period. In an effort to help the farmer solve his immediate problems, the agronomist conducted thoroughly planned cooperative experiments on individual farms, where, among other things, crops forming the basis of the dairy and poultry industries were tested. In March, 1923, the agronomist left the station for a four months' trip to the Orient, where he will make a study of general-farming and poultry-raising methods applicable to Hawaiian conditions.

Work in the chemical division was devoted to the solution of problems arising in connection with the development of the starch industry and the preservation of various fruits and fruit products. Tests are being continued to determine the effect of soil, locality, and climate on the mineral constituents of Hawaiian-grown vegetables, and the effect of brackish irrigation water on certain crops growing on sand, loam, and clay soils. Fertilizer experiments with bananas and fertility-rotation experiments with pineapples and upland sugar cane are also being carried on.

In addition to traveling over 11,000 miles to visit and assist homesteaders, poultrymen, plantation managers, and ranchers, the extension agent for the island of Hawaii gave much of his time and attention to directing the work of the cooperative experiment station at Glenwood, cooperative work on the Parker ranch, Kamuela, to the fruit-tree nursery near Hilo, and to garden and club work in the schools. The general-extension activities of the central station extended to all the outlying islands, and included many kinds of service.

The station continues to maintain two substations, one at Glenwood, Hawaii, and the other at Haleakala, Maui. The former is operated as a well-balanced stock farm with dairy cattle predominating. Data obtained in experiments carried on at this farm are passed along by the extension agent to farmers similarly situated throughout the islands. At the Haleakala substation and demonstration farm investigations were made to determine the cultural requirements and adaptability of a large number of crops to the somewhat unfavorable climatic conditions prevailing on the slopes of the Haleakala volcano.

In the division of home-demonstration activities very pleasant relationships were established with various Territorial institutions and manufacturing concerns, and large groups of women, representing many nationalities, were reached by the collaborator in charge.

Under the direction of a club leader, boys' and girls' club work is being conducted in cooperation with the University of Hawaii, the Star-Bulletin Garden Contest Association, the Young Women's Christian Association, the Salvation Army Boys' Home, and the public schools.

At the central station a number of the buildings were repainted and several of the roofs were retreated with graphite paint to protect the shingles. Two cesspools were dug to improve the sanitary condition of the station dwellings. A thief-proof fence was built around the various experimental plats, and a start made toward fencing the experimental plats at the Tantalus substation.

During the year the following publications were issued by the station: Annual Report for 1921; Bulletin 48, Swine Raising in Hawaii, by F. G. Krauss; Bulletin 49, The Acid Fruit Lime in Hawaii, by W. T. Pope; and Bulletin 50, The Sweet Potato in Hawaii, by H. L. Chung.

REPORT OF THE HORTICULTURAL DIVISION.

By W. T. Pope.

AVOCADOS.

Studies were made of the growth of trees, habits of productivity, and quality of fruit of about 90 varieties of avocados. Many of the promising sorts were described and photographed for future record, and propagating wood of the better varieties was obtained for experimental work. The winter avocado is especially promising, since apparently it can be made to bear and ripen its fruit during the months of the year when the ordinary summer avocado is not in season. The fruit has a high food value, containing approximately 18 per cent of fat.

The nonbearing habit of certain avocado trees is now one of the most vital problems confronting growers. This trouble is similar to that reported from Florida and California, where a rather extensive study showed that the nonbearing condition is due to a failure in pollination. It is concluded from a study of the flower in relation to methods of pollination, begun at the station during the last blossoming season, that cross-pollination is necessary, at least with certain varieties, to assure satisfactory crop production, and the interplanting of varieties is recommended. Pollination experiments will be continued with the next blossoming season.

In most instances Hawaiian soil conditions are such that it is impracticable to raise budded or grafted avocado trees in nursery rows prior to transplanting them elsewhere. Growing trees in flowerpots, tin cans, and wooden boxes is an unsatisfactory method, owing to the complications which arise before the trees attain sufficient size and strength to permit of their being transplanted to the open. Although budding has been considered the best method of propagating varieties of avocado, budded trees invariably fail to make satisfactory growth. At the station an improved method of grafting very young seedling avocados is followed, using as scions the tender terminal shoots of desirable varieties. It is thought that this method will greatly reduce the time required to get young grafted trees in condition for transplanting.

In connection with propagation work, a study of avocado rootstocks was made during the year. Although local propagators prefer Guatemalan seedling rootstocks to either the West Indian or the Mexican rootstock in propagating varieties of Guatemalan avocados, results obtained from rather extensive experiments made at this station would seem to indicate that the Guatemalan is not superior to the West Indian rootstock, particularly when the seeds used in growing the stocks have come from fruit of good quality. These in-

vestigations also confirm results of studies in other parts of the world with asexual methods of propagation. Due to the similarity of their natures, both the Guatemalan and the West Indian types may be united by budding and grafting. Further investigation may show a definite advantage of some one combination over another.

MANGOES.

Several new varieties of mango trees, having fine qualities of productivity and flavor of fruit and showing immunity to attacks of the Mediterranean fruit fly, were added to the station collection during the year. Continued wet weather favored the development of a fungus disease (due to *Glœosporium mangiferæ*) at the time many of the trees were in blossom, and as a result a number of the flowers dropped and young foliage and fruit in various stages of development became splotched with black. Sprayings with Bordeaux mixture and lime-sulphur were ineffective, owing to the frequency of showers. Only part of the crop was destroyed, however, and trees blossoming later are now bearing their full crop of fruit. Mango trees in nearly all parts of the Territory showed great resistance to wind in a severe three-day wind and rain storm occurring in January, 1923, the branches remaining unbroken.

Some of the seedling mango trees of Victoria No. 9 are attracting considerable attention by producing fruit identical with that of the parent tree (Mango No. 9). The seeds of the latter are polyembryonic, which it is thought gives one seedling as the result of cross-pollination and several vegetative (parthenogenic) forms producing fruit very closely resembling that of the original parent tree.

Attempts to graft young seedling trees with scions of desirable varieties by a modified form of the side tongue-graft method were 96 per cent successful. This method is an improvement of 46 per cent over the other methods hitherto used most successfully.

BREADFRUIT.

In an experiment undertaken to develop plants from root cuttings of the seedless breadfruit tree, 400 young trees were produced from 600 five-inch cuttings taken from the surface roots. This very nutritious and wholesome fruit has practically ceased to be used in the Territory, mainly because of the difficulty with which the tree is propagated.

BANANAS.

Thirty-five different varieties of bananas are being grown at the station, and studies are being made to determine the best varieties of the so-called cooking bananas. Kona Maimaoli appears to be the best. This variety has a fine flavor, produces bunches weighing from 90 to 100 pounds, and is undoubtedly the finest of the varieties for shipping. The plants do not withstand much wind, but they do exceptionally well in the Kona district, where conditions seem to be the most favorable to growth. Varieties suitable for use as fresh fruit include the Chinese, Brazilian, and Bluefields, only the first of which is as yet grown extensively enough for shipping.

PAPAYAS.

The results of the papaya investigations continue to be encouraging. The plant responds quickly to favorable conditions. Several varieties, imported from other parts of the world, have as yet shown little difference from the varieties already grown. Two of the leading sorts, Station Accession No. 4618, a long variety, and Station Accession No. 4617, a round variety, continue to produce fruit of high flavor and flesh which remains firm during the cool wet months of January and February when other kinds are inferior in quality.

CITRUS FRUITS.

Experiments are being carried on with oranges, limes, lemons, pomelos, shaddocks, and citron, and budded trees of the Hawaiian (Polynesian) orange are being propagated from the best selected trees of the Kona district where citrus trees do well. The cooperative experimental work, covering two 1-acre plats and directed toward the standardization of this excellent variety, is making very fine progress. About 400 budded trees have been distributed to cooperative growers throughout the Territory. The orchard at the central station contains miscellaneous varieties of many kinds of citrus, all of which are doing well. Cowpeas, intercropped with citrus, made the most efficient green-manure crop of the several kinds under trial during the winter months.

GRAPES.

Trial plantings of the famous currant grapes of Greece are being made on the semiarid steep hill and mountain sides to determine the possibility of establishing a currant industry in Hawaii. The station has a number of varieties under test, including the Isabella, Concord, Tokay, Cornichon, Thompson's Seedless, Almeria, Zante, Malaga, fox, muscadine, Niagara, Scuppernong, Golden Queen, and a tropical grape (*Vitis tiliæfolia*). Isabella, a very prolific variety and well adapted to island conditions, may be made to ripen its fruit every month of the year. New varieties possessing desirable qualities are being grafted on Isabella rootstocks, and experiments are being made to determine the effect of pruning at different seasons on time of fruiting. Several thousand rooted plants were distributed during the year.

TOMATOES.

Tomato investigations are of importance in that they have for their object the production of varieties that will resist attacks of the Mediterranean fruit fly. So far, very few of the progeny from cross-pollinations have closely approached the ideal type. In progress is another experiment in which are being grown many desirable types having habits as well as characters to be combined, it is hoped, in the new and more substantial type.

NUTS.

The nut investigations of the year were confined to five species, the Macadamia, pistachio, walnut, almond, and cashew, and as yet have resulted in little more than making these nuts known to growers. Nut culture has excellent possibilities in Hawaii.

INTRODUCTION AND DISTRIBUTION OF NEW AND IMPROVED PLANTS.

Approximately 150 new varieties of plants were received by the station from the Bureau of Plant Industry, United States Department of Agriculture, and from interested persons living in various parts of the world. Many of these plants are of economic value in their native land and already give indications of being of value in Hawaii.

In addition to distributing a large number of thoroughly tested plants to interested growers throughout the Territory, the horticultural division also supplied limited quantities of new plant material, which had not been fully tried out by the station, to especially selected cooperative growers who are willing to assist in determining the value of new plants in various parts of the Territory.

REPORT OF THE AGRONOMY DIVISION.

By H. L. Chung.

Severe rain and wind storms occurring in the middle of January so severely damaged newly planted experimental plats as to necessitate replanting many of them. Root crops escaped more or less, and a large part of the corn matured sufficiently for harvesting.

GRASSES.

Napier grass (*Pennisetum purpureum*) is demonstrating its value as a forage crop for dairy cattle by rapidly putting out vigorous growth after a crop is cut for green feed. Many thousands of cuttings have been furnished to local dairymen for propagating purposes.

Guatemala grass (*Tripsacum laxum*) this year bloomed for the first time since it was planted, in August, 1919.

UBA CANE.

During the year Uba, or Japanese, cane tasseled. It has been extremely difficult to get this cane to flower, and when tasseling did occur, the station, working in cooperation with the Hawaiian Sugar Planters' Association, hybridized the variety with pollen from the best sugar cane varieties available for the production of a superior progeny. The hybrids are under observation and will be thoroughly tested to determine their sugar-producing possibilities and their adaptability to local conditions, especially with regard to ability to resist disease.

SWEET POTATOES.

During the year a test was made to determine the comparative yields, quality, and ability to resist fungus and insect attack, of 34 native varieties of sweet potatoes from Kauai and Maui and 37 varieties from the mainland. All but 5 of the imported sorts were grown for the first time at this station. Comparison of the native varieties with those grown at the station has shown the latter to be true to name as originally given by the native Hawaiians. The following table gives the comparative yields of native and imported varieties:

Comparative yields of locally grown and imported varieties of sweet potatoes.

Station No.	Locally grown varieties.	Calculated yield per acre.	Station No.	Imported varieties.	Calculated yield per acre.
		Tons.			*Tons.*
1596	Mohihi	2.04	1563	Yellow Jersey	2.22
1597	Manana	8.17	1564	Big Stem Jersey	3.74
1598	Mahina	4.88	1568	Big Leaf Improved	3.97
1599	Pu	4.22	1550	Big Leaf	3.06
1600	Manuia	2.89	1553	Early Carolina	3.28
1601	Kiikiki	2.38	1549	Waite's Improved Big Stem	1.02
1602	Mohihi	2.83	1571	Early Carolina	2.22
1603	Mauaniana	2.38	1578	do	2.22
1604	Naleimaile	2.22	1556	Porto Rican	3.51
1605	Pikolehua	2.49	1562	Triumph	6.01
1606	Kauai	1.70	1548	Dixie Yam	5.33
1607	Koloa 1	1.87	1551	Old Long Red	1.70
1608	Koloa 2	7.26	1547	Jewel Yam	1.59
1609	Koloa 3	4.25	1554	Belmont	2.15
3844	New Era	5.96	1555	New Gem	3.17
1611	Kapaa	3.85	1570	Creola	2.04
3842	Madeira	2.25	1575	Vineless	1.93
3838	Delicious Yellow	0.73	1574	General Grant Vineless	5.56
3874	Tantalus	2.69	1566	Japanese Brown	3.40
98A	Seedling	3.17	1582	Myers' Early	3.88
3871	Yellow Yam	2.94	1572	Pumpkin Yam	3.88
88A	Seedling	2.89	1573	Pierson	5.96
114C	do	4.93	1519	Yellow Yam	3.74
3856	do	2.95	1559	Southern Queen	1.93
111A	do	2.65	1569	Miles' Yam	1.93
3856	Puukeokeo	2.89	1576	Norton Yam	2.61
3845		3.74	1581	Shorthorn	4.42
39		3.40	1584	Enormous	6.24
1324		3.57	1577	Pumpkin Yam	2.95
3851	Kikola	2.89	1583	Yellow Strasburg	5.10
1345	Berlina	4.09	1561	Nancy Hall	1.81
56		2.38	1560	do	2.49
439		2.20	1580	Red Bermuda	6.35
3840	Laupahoehoe	2.38	1565	Japanese Brown	1.36
			1567	Red Jersey	3.74
			1591	Porto Rican	5.07
			1592	Triumph	4.53

MANGEL WURZELS.

The varieties Giant Yellow Intermediate, Long Red, Yellow Globe, and Golden Tankard, obtained from England for trial as a winter crop, were planted September 8, 1922, and harvested March 8, 1923, yielding approximately 2.58, 1.35, 1.46, and 3.31 tons, respectively, per acre. Giant Yellow Intermediate and Golden Tankard made the heaviest yields and continued to grow when the other two varieties appeared to be in a dormant condition.

SUNN HEMP.

Sunn hemp (*Crotalaria juncea*) continues to give great promise as a green manuring crop, especially in connection with wornout pineapple lands. In culture tests made during the year, seed was produced at the rate of 1,038 pounds per acre. Requests for seed came from the mainland as well as from local homesteaders and pineapple growers. Selection work for improvement in foliage and seed is under way, it being the desire of the station to develop leguminous green-manure crops which will not only make efficient cover crops and produce seed, but will also quickly produce an abundance of green manure for plowing under for soil-improvement purposes. Sunn hemp and pigeon peas are the most promising of the various green-manure crops now under test.

DISTRIBUTION OF SEEDS AND CUTTINGS.

The production of seeds and cuttings early in the last fiscal year enabled the station to meet the unusually heavy demands of the present year. A large part of the distributions were made to schools for school-garden work. In addition to 510 corms or tubers of edible canna, distribution from July 1, 1922, to June 30, 1923, was made in amounts as follows:

Seeds and cuttings distributed during the fiscal year ending June 30, 1923.

Crop.	Cuttings.	Seed.	Crop.	Cuttings.	Seed.
	Number.	*Pounds.*		*Number.*	*Pounds.*
Guam corn	----------	211	Napier grass	47,434	----------
African sorghum	----------	8	Merker grass	10,408	----------
Yam beans	----------	3	Pigeon peas	----------	54
Hybrid cowpeas	----------	130	Alfalfa	----------	25
Velvet beans	----------	7	Crotalaria	----------	70
Clover	----------	3	Beans (all varieties)	----------	158
Peanuts	----------	33	Bermuda grass	2,746	----------
Uba cane	3,446	----------	Sweet potatoes	7,601	----------

POULTRY.

The poultry work was carried on along essentially the same lines as last year. Considerable time was devoted to demonstration work in flock improvement and the treatment of disease. The poultry department of the University of Hawaii was assisted in conducting its first egg-laying contest, and each contesting hen was examined for characteristics indicating egg-laying capacity. Local poultrymen were materially aided in obtaining desirable breeding and laying stock, over 5,000 such fowls being imported between November, 1922, and February, 1923. Poultry raising is being carried on on a rather extensive scale on Maui. The district of Makawao is ideal for poultry raising. Homesteaders on this island were assisted in drawing plans for poultry houses and in overcoming problems connected with poultry management.

REPORT OF THE CHEMICAL DIVISION.

By J. C. Ripperton.

BANANAS.

Fertilizer experiments with the Chinese banana have almost without exception given negative results in past years. That some form of fertilizer is needed, however, is proved by the stunted appearance of the plants and the growing of the fruit in small bunches in many fields. Climatic factors are not the cause, since certain fields in a given locality produce excellent bananas, while others closely adjacent and given similar treatment yield very inferior fruit. As a result of rather elaborately planned fertilizer experiments carefully carried out during recent years by the station and individual growers, as well as of observations of the nature and feeding habits of the plant, it is concluded that in certain sec-

tions the banana is prevented by adverse soil conditions from utilizing the plant food applied. Results of analyses of the seepage water at the lower boundary of a fertilized field to determine the effect of heavy applications of irrigation water on leaching of the readily soluble fertilizer from the feeding zone of the plants, showed a very appreciable leaching of all the fertilizer elements. Accordingly, an experiment was begun to determine the best method of applying fertilizer to the crop. The same quantity of a complete, ready-mixed commercial fertilizer was applied to each plat, and four different methods of application were used. In the first test the total quantity was applied at one time about the base of the plant; in the second test the total quantity was placed in the sides of the furrow and about the level reached by the water during irrigation; in the third test the total quantity was given in six monthly applications about the base of the plant immediately before irrigation; and in the fourth test the total quantity was given in six monthly applications about the base of the plant immediately after irrigation. The first crop of the experiment has been harvested and fertilization of the second crop completed. It is expected to carry this experiment through two more crops.

Pot and field experiments are to be conducted to permit a study of the general feeding habits of the banana, its susceptibility to various soil toxins, and the physical properties of the soil affecting growth.

FERTILITY-ROTATION EXPERIMENTS WITH PINEAPPLES, UPLAND SUGAR CANE, AND PIGEON PEAS.

This experiment was undertaken to determine the feasibility of providing rotations for pineapples and sugar cane and at the same time preventing the usual soil depletion accompanying the single-crop system by growing pigeon peas as a green-manuring crop. The decrease in yields with continuous cropping to pineapples is very manifest in Hawaii. A fertilizer experiment is being carried on in conjunction with the rotation experiment. The experiment has been carried through two crops each of pineapples and sugar cane, and the pigeon pea crops have been alternately plowed under and removed. The pineapple and sugar-cane areas are being plowed at the end of the second crop harvest, and the second step in the rotation will be begun this fall (1923) when the pineapple plat will be planted to sugar cane, the sugar-cane area to pigeon peas, and the pigeon pea area to pineapples.

HAWAIIAN STARCHES.

Investigations were continued with various tropical starches to determine the more scientific phases attending their commercial development.

Tree fern.—Experiments with the tree fern for the production of starch were concluded. It has been found that, relative to replanting cut-over areas, an average of three young tree ferns can be obtained from each felled mature tree fern. The rate of growth of this genus is, however, too slow to make it commercially practicable to replant the tree fern for its starch content.

Edible canna.—Preliminary investigations on certain phases of the culture of edible canna and the properties of its starch were completed, and the following conclusions drawn: The chemical composition of a hill of edible canna is fairly constant, regardless of its age. Although there is considerable difference between the mature and the immature type of tubers, the hill as a whole remains practically constant. The feeding value of the edible canna, both tubers and tops, is about the same as that of the other common tuberous and nonleguminous forage crops. Canna starch is characterized by its unusually large granules, and its properties are similar to potato starch. It is thought to have possibilities as an industrial starch.

Edible canna investigations are being continued. A fertilizer experiment has been begun to learn the best method of applying fertilizer to the crop, and another has been planned to ascertain the fertilizer formulas best adapted to it. Cooperative investigations have been undertaken with a local starch company to solve the problems incident to the manufacture of the starch and the utilization of the by-products.

JELLY MAKING FROM TROPICAL FRUITS.

In an attempt to introduce into commercial jelly making in Hawaii more scientific methods than are now used, the chemical division conducted experiments with fruit juices for pectin and acid, determined the proper sugar ratios, and made a study of the resulting products.[1] Much of this work has been carried on in cooperation with a local jelly company.

Preliminary work has been started to determine the feasibility of using commercial pectin in making certain tropical jelly and jam products. Various formulas for its use are being developed, and studies made of the relative cost and palatability of the resultant products. Work of a more fundamental nature is being undertaken to determine the physical differences in the pectins of different fruits, the relative "gelling strength" of each pectin, and the character of the gel produced.

EFFECT OF CLIMATE AND SOIL ON THE COMPOSITION OF HAWAIIAN VEGETABLES.

The opinion prevalent among certain classes in Hawaii that locally grown vegetables are lacking in certain essential mineral constituents is not without scientific foundation. Shorey[2] found the forage crops of the island deficient in lime, and Johnson[3] showed that pineapples are unable to assimilate iron from certain soils. As a result of this opinion, locally grown vegetables are discriminated against in favor of canned products from the mainland. Preliminary analyses of a series of spinach samples grown on the mainland and in Hawaii, indicated that generally this vegetable is richer in mineral constituents than is the mainland spinach. In a rather extended experiment, planned to determine the effect of tropical climate and volcanic soil on the composition of vegetables, two leaf vegetables (spinach and cabbage), two root vegetables (carrots and

[1] Hawaii Sta. Bul. 47, Applications of the principles of jelly making to Hawaiian fruits, by J. C. Ripperton.
[2] Hawaii Sta. Bul. 13, The composition of some Hawaiian feeding stuffs, by E. C. Shorey.
[3] Hawaii Sta. Press Bul. 51, The spraying of yellow pineapple plants on manganese soils with iron sulphate solutions, by M. O. Johnson.

beets), and two pod vegetables (peas and beans), were selected for study. Seed was obtained from a reputable firm and planted in two widely separated areas on the mainland (Virginia and Washington), and likewise in two localities on Oahu. The vegetables from each place were dehydrated and together with a sample of the soil in which they were grown were sent to this station for analyses. Both vegetables and soils are now being analyzed.

SALT TOLERANCE OF VARIOUS PLANTS GROWN IN SAND, LOAM, AND CLAY SOILS.

Extensive investigations were made to determine the tolerance of various crops to brackish irrigation water and with soils derived from igneous and metamorphic rock and under Temperate Zone conditions. Data on the tolerance to sodium chlorid of various crops grown on volcanic soils and under tropical conditions are rather fragmentary; and likewise, both the nature and extent of the physical and chemical effects of this salt on volcanic soils are unknown. The investigations included lysimeter, laboratory, and field experiments.

Lysimeter experiments.—Typical soils of Hawaii were placed in lysimeters and planted to alfalfa (Pl. I, fig. 1), Napier grass, rice, sugar cane, and carrots. The effect of varying concentrations of sodium chlorid in the irrigation water upon the growth of the several crops was studied and the leachings from the lysimeters were collected and analyzed. (Pl. I, fig. 2.) These studies will be carried through two or three crops to determine the cumulative effect of the salt upon the soil.

Laboratory experiments.—Studies were made of the physical and chemical changes taking place in the soils used in the lysimeter experiments, and also of soils taken from various districts which have been irrigated with brackish irrigation water for many years. Field observations and laboratory tests thus far conducted indicate that these changes are very appreciable and eventually will become a serious menace to the productivity of the soil.

Field experiments.—The salt content of both water and soil was determined in the important districts using brackish irrigation water, and the character of the crops and condition of the soil were noted. During the year two crops were grown in the lysimeters. Methods were devised for ascertaining the physical changes taking place in these soils. The irrigation water used on the islands of Kauai, Hawaii, and Oahu was tested and soil samples collected for further study.

REPORT OF EXTENSION AND DEMONSTRATION WORK ON THE ISLAND OF HAWAII.

By R. A. Goff.

GLENWOOD SUBSTATION AND DEMONSTRATION FARM.

F. X. Helbush, the collaborator in charge of the Glenwood substation and demonstration farm, is making every effort to maintain this farm as a self-supporting unit. During the year the dairy herd increased to 31 head, 7 of which are young females. A registered

Holstein bull now heads the herd. Eight heifers will come in this year, bringing the milking herd up to 15. Three old Berkshire sows and two of the best of their litters are being kept. The purebred White Leghorn poultry flock increased from 300 to 475 laying hens. It is planned to increase this flock to 800 laying hens this year and to 1,000 the year following, and during these two years to bring up the dairy herd to 20 milking cows. Napier grass and pigeon peas are being grown to help feed the animals. The eggs, cockerels, butter, calves, and hogs will be marketed locally. Muscovy and Pekin ducks were purchased as foundation stock for the production of progeny for experimental purposes.

Farm buildings for the animals were altered and enlarged during the year. A 40-foot extension was added to the cow stable, an iron-roof shed was erected for the hogs, an iron-roof awning was placed in front of the barn, and a new fence was built around the 30-acre pasture lot. New roofs were put on the poultry houses, and the yards were rearranged to permit of larger runs. A dwelling for a laborer who also acts as night watchman was erected near the poultry houses, and a water tank having a 10,000-gallon capacity was built. Two others of the same size were purchased and will be put up this year.

WORK AT THE KAMUELA COOPERATIVE EXPERIMENT STATION.

The Kamuela Experiment Station is operated by the Parker ranch. The area in pasture grasses and field and forage crops was enlarged during the year, and such crops as Russian brome, redtop, Harding grass, Peruvian winter grass, *Paspalum larranagai*, *P. notatum*, *Phalaris bulbosa*, Australian tall fescue, purple vetch, alfalfa, and sweet clover, which looked promising at the end of the first year, were planted in one-third acre plats. Selected seed of corn grown last year is being planted in six areas totaling 2 acres. Seed of 16 kinds of range grass, obtained through the Montana Experiment Station from varying altitudes and from wet and dry localities in Montana, will be planted in small plats to test their adaptability to conditions prevailing in the ranching districts of Hawaii. Seeds, cuttings, and roots of crops growing well at the station were distributed to homesteaders in the Kamuela district and to dairymen and ranchmen in Kona, Kau, and near Hilo.

GENERAL ACTIVITIES OF THE EXTENSION AGENT.

Talks to school children and homesteaders.—Talks on gardening and garden crops were given to school children at morning assembly; spraying and proper methods of cultivation demonstrations were conducted; and discussions were given on seed varieties and depth of planting. Illustrated lectures on butter making, pruning, and budding, as well as discussions of crops best suited to the different localities, poultry, dairying, and hog raising, were given assembled groups of homesteaders in the various districts.

Boys' club work.—Each interested child of the island schools having a sixth or higher grade, was given a quantity of corn and seed potatoes sufficient to plant a minimum of 1,000 square feet. Bulletins on corn and potato growing were distributed to the young gardeners, and arrangements were made with a local poultryman to

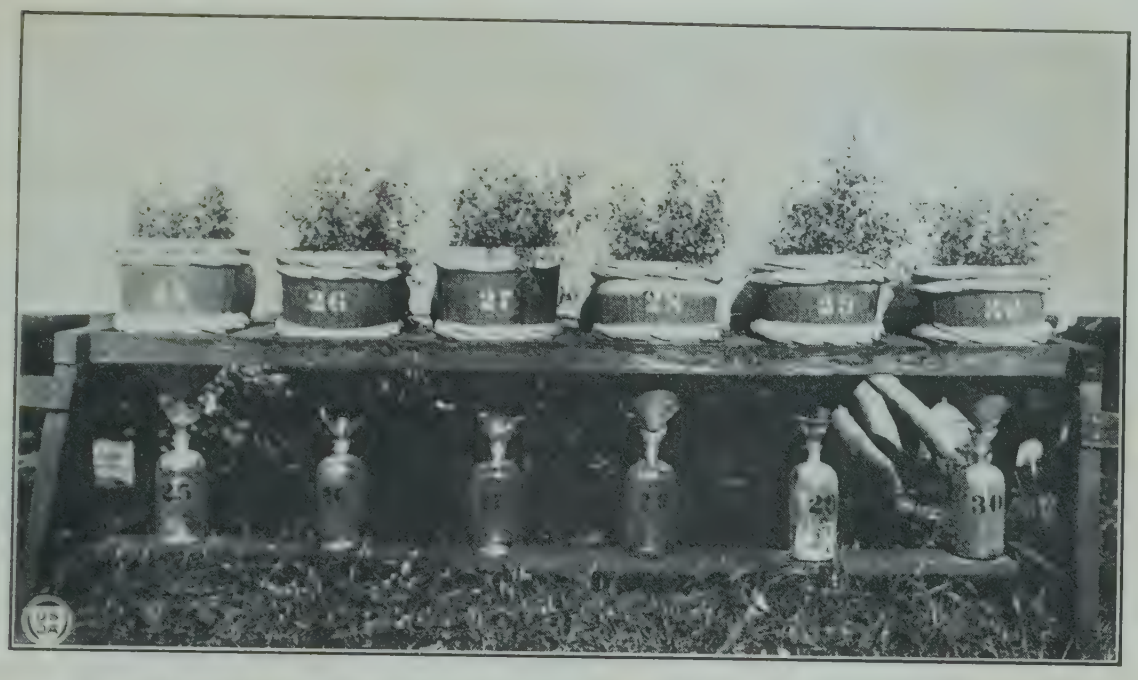
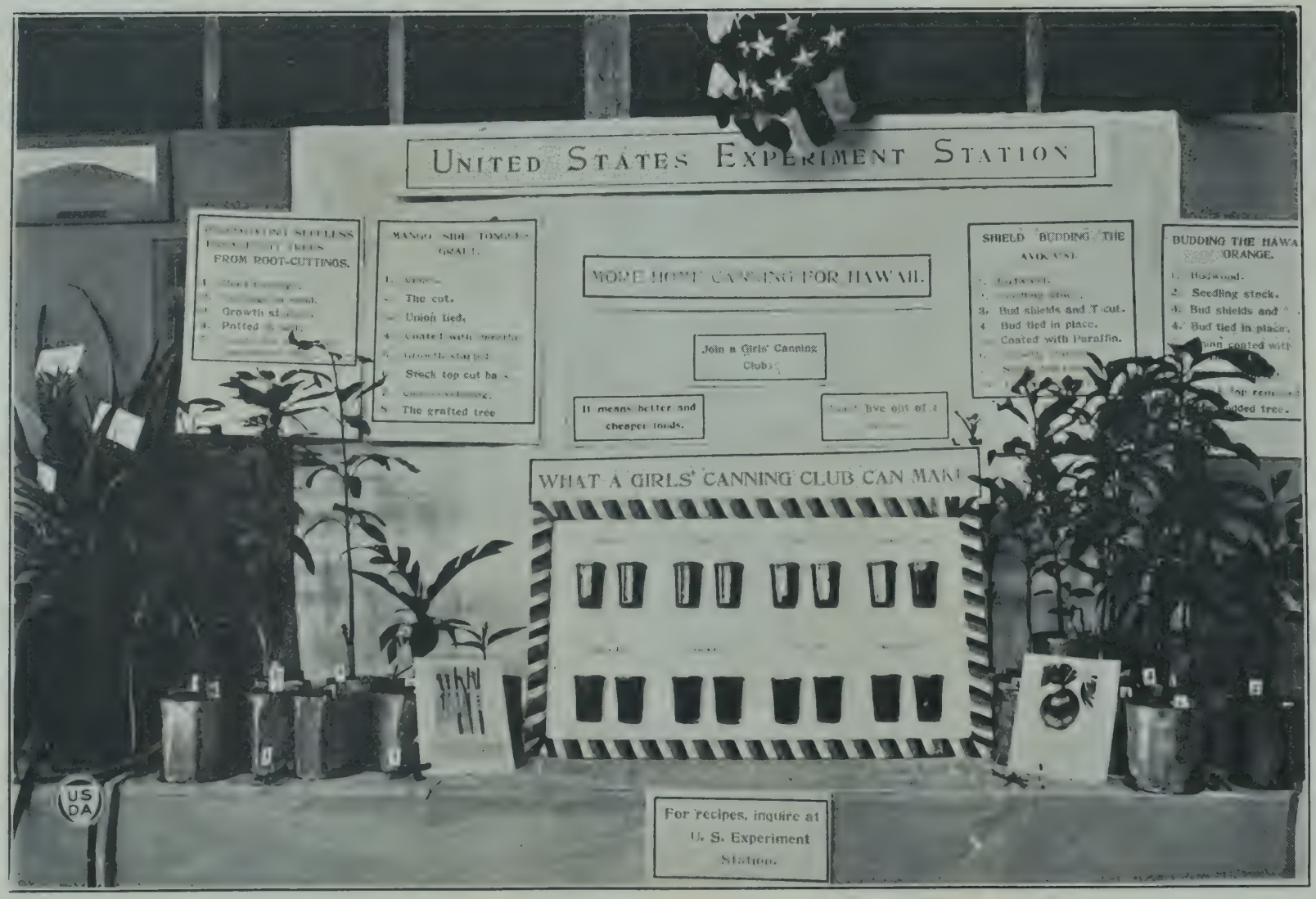


FIG. 1.—METHOD OF DETERMINING SALT TOLERANCE OF ALFALFA.

FIG. 2.—GENERAL VIEW OF LYSIMETERS IN SALT TOLERANCE EXPERIMENTS.


UNITED STATES EXPERIMENT STATION
FROM ROOT-CUTTINGS.
MANGO SIDE TONGUE GRAFT.
The cut.
Union tied.
Stock top cut ba
The grafted tree
MORE HOME CANNING FOR HAWAII.
Join a Girls' Canning Club
It means better and cheaper foods.
SHIELD BUDDING THE AVOCADO.
3. Bud shields and T cut.
4 Bud tied in place.
Coated with Paraffin.
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1. Rootstock.
2. Seedling stock.
4. Bud shields and
4. Bud tied in place.
WHAT A GIRLS' CANNING CLUB CAN MAKE
For recipes, inquire at U. S. Experiment Station.
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EXHIBIT OF HAWAII STATION EXTENSION DIVISION AT AGRICULTURAL FAIR.

supply a setting of eggs to each boy interested in poultry work. Chickens were hatched and raised to 3 months of age, at which time they were exhibited at the county school fair and the poultryman was given his choice of one pullet to pay for each setting of eggs. Farmers' Bulletins on feeding and raising chicks were distributed to the boys and visits made to their homes, where assistance in making chicken coops and runs was given. Various problems were discussed at monthly meetings.

School and home-garden work.—Thirty schools entered the school-garden contest during the year with gardens ranging from one-fourth of an acre to 3 acres. Seed of corn, potatoes, alfalfa, pigeon peas, and sweet clover, together with instructions regarding each crop, were given to the children of 12 of the schools. Several times during the year the schools were visited and the extension agent acted as one of the judges in the different districts at the close of the contest. The island was divided into two main districts in the home-garden contest, which made it possible to have the children of each garden compete with those of the same grade in each of the two districts.

Hawaii school fair.—The best products from the gardens of the whole country were displayed in the agricultural section of the Hawaii school fair. Fully 4,000 children visited the fair. Pupils and teachers obtained the names of varieties of seed doing well in schools other than their own for the purpose of planting the most successful kinds in the future. The extension agent acted as chairman of the agricultural committee, and entry lists were made out, interest in entries was aroused in the different schools, judges were secured, exhibits displayed, and awards sent to the winners.

Seed distribution.—Owing to difficulty in obtaining sufficient feed for cows, pigs, and poultry, especially in the sugar-cane districts, where large areas are devoted to cane growing, the extension agent persuaded homesteaders in each district to prepare a plat for various field crops and distributed seed of corn, alfalfa, and sweet clover, and cuttings of Merker grass, Napier grass, and Uba cane. Sweet potato cuttings and vegetable seeds of varieties suited to the different localities were also distributed. The seed of the Solo papaya, which is a good table variety, and of a larger growing papaya for use as a hog feed, was given to those requesting it.

Distribution of literature.—United States Department of Agriculture Farmers' Bulletins and bulletins published by the station on vegetable gardens, field and forage crops, livestock, and farm buildings were distributed during the year. Extra copies of seed-house catalogues were obtained for those requesting them, and newspaper articles dealing with agricultural topics of especial interest were loaned to various farmers.

Assistance in marketing.—Samples of products grown in the Kamuela and Kona districts were taken to dealers in Hilo, and arrangements made for future shipments. Demonstrations were given producers in proper methods of sorting and grading, and suitable containers were obtained for them. Dealers who have been purchasing a large supply of potatoes, poultry, and dairy supplies from the mainland cooperated in marketing the local produce. The extension agent also assisted in marketing sweet corn, rhubarb, and avocados.

Assistance in boy scout activities.—The extension agent continued to act as scout commissioner for the island and as examiner for boy scouts competing for the agricultural merit badge.

Fruit tree nursery.—Buds from grapefruit and navel and Kona orange trees were grafted on 300 wild-lemon seedlings, and more than 500 avocado seedlings were worked over into winter-bearing trees. Many of them were distributed to different parts of the country and withstood transplanting without injury. About 800 citrus seedlings are now ready for budding and as many avocado seeds are being planted for the coming year.

Spraying demonstrations.—In the Kohala and Hamakua districts, where growers experience difficulty in keeping pineapple plants in a healthy growing condition, due to lack of available necessary plant food in the soil, demonstrations of the proper methods of treating the soil were conducted. Demonstrations were also given of the preparation and application of Bordeaux mixture as a control measure for potato blight occurring in the Hamakua, Kamuela, and Kona districts; as well as of poison bait for cutworms, and Paris green and arsenical mixtures for garden pests occurring in the volcano district near Hilo.

Assistance in planting windbreaks.—Seed and seedlings of eucalyptus, black wattle, Monterey cypress, and ironwood trees were distributed in the Kau, Kohala, and Kamuela districts.

Miscellaneous activities.—Active assistance was given farmers in bringing in from the mainland at least 5,000 laying hens. Assistance was also given in culling the fowls in an egg-laying contest conducted by the University of Hawaii. Demonstrations of the proper methods of utilizing locally grown fruits and vegetables were carried on in cooperation with various Territorial agencies which are interested in nutritional work with underweight children. In an effort to cultivate a liking by the people for milk and butter as well as for home grown fruits and vegetables demonstrations were also given setting forth the value of fresh, locally produced food products. At some of these meetings the members of the extension division came in contact with parents as many as 520 times during a single month.

HALEAKALA SUBSTATION AND DEMONSTRATION FARM.

By H. F. Willey, *Superintendent.*[4]

At the Haleakala substation and demonstration farm, where normally the rainfalls are light and the winds high, unusually heavy torrential storms occurred during the year. Several rows of *Eucalyptus robusta* were successfully established as windbreaks along the windward side of the farm, and Napier grass and Uba cane were set as secondary windbreaks at intervals across the farm rows. A road was constructed across the gulch dividing the farm unit into two sections, and the roadway leading from the main road to the residence and farm buildings was improved. The field as a whole was given deeper tillage than formerly, and, as a result, the crops are responding satisfactorily. Approximately 194 varieties of 74

[4] Temporarily employed.

crops were planted, including pineapples, pigeon peas, field corn, sweet corn, pop corn, tomatoes, and sweet potatoes. Fully 600 visitors to the farm inspected the various plantings.

In addition to assisting with school-garden activities and the Maui County Agricultural Fair held in October, 1922, the superintendent gave suggestions to homesteaders relative to improved methods of planting and tillage, selected and ordered seed for homesteaders, and obtained prices on fence material and purebred stock for them.

REPORT OF HOME DEMONSTRATION ACTIVITIES.

By Mrs. Nellie A. Russell.

The home-economics demonstrator again instructed groups of Japanese, Chinese, Philippine, Portuguese, and Hawaiian women in the art of home making in harmony with American ideals. These women are anxious to learn methods that are an improvement over those to which they have been accustomed, especially in regard to the utilization of local fruits and vegetables. A large number of the demonstrations were given with the assistance of interpreters to groups of working mothers during the noon hour. Rooms were provided for the occasion by the various business concerns which have become interested in this phase of Americanization work among the several nationalities. Special instruction and demonstrations in cooking and serving meals, as well as lessons in dressmaking and millinery, were given to older girls. The sewing classes require a great deal of individual attention, since the teaching of sewing does not lend itself readily to group presentation.

BOYS' AND GIRLS' CLUB WORK.

By Mabel Greene.

As soon as the club leader arrived in Hawaii in April, 1923, efforts were made to have the boys' and girls' club work correlated with the work of the public schools under the direction of teachers who are trained in agriculture and home economics. The public schools, beginning with the fifth grade, have a very definite place in their curricula for these studies. Club members are also receiving instruction in how to keep records, conduct business meetings, and assist in public demonstration work. The latter activity has a far-reaching influence upon the older people in each neighborhood. During the year club work was organized in three districts in Honolulu. Canning, dairy, garden, rabbit, poultry, home-management, and sewing clubs were organized, with an enrollment of 110 members. Considerable time was spent in studying local conditions and in establishing pleasant cooperative relationships for conducting the work. The garden club work embraces 46 members at the Salvation Army Boys' Home, where a new tract of land has been made available. Agricultural slides, furnished by the United States Department of Agriculture, were shown at the various meetings by

means of a stereopticon; and corn, beans, and peanut seed, together with young papaya trees and sweet potato cuttings, were distributed to members. Demonstrations of the best methods of planting were given at the time the distribution was made.

A group of girls, ranging in age from 16 to 18 years, are studying home-management problems in coopertaion with the club department of the Young Women's Christian Association. They have already learned how to use the fireless cooker and are planning to make one for their club rooms, which they are furnishing. These girls have completed a luncheon set and expect to learn canning work during the July and August meetings.

The school fair in Honolulu, May 25 and 26, 1923, afforded an excellent opportunity for parents and others interested to view the agricultural and home-economics work being done in Maui, Hawaii, and Oahu by the boys and girls. The extension agent served as a judge of the cooking contest held May 26. Club work will be closely affiliated with contest work, but separate club records will be kept and public demonstrational work will receive increased emphasis. The exhibit of local food products of the central station was allotted space in the Territorial Normal School exhibit (Pl. II). The club leader will meet the teachers attending the summer session, June 25 to August 3, 1923, to tell them of the purpose of the boys' and girls' club work and explain to them how they can assist in furthering it.

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HAWAII AGRICULTURAL EXPERIMENT STATION
HONOLULU, HAWAII

Under the supervision of the
UNITED STATES DEPARTMENT OF AGRICULTURE

Washington, D. C. July, 1926

REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION, 1925

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SUMMARY OF INVESTIGATIONS

By J. M. WESTGATE, *Director*

The station continued to investigate the various problems affecting the production, marketing, and utilization of food and forage crops, and to formulate plans for developing such agricultural industries as can be promptly launched in case of some calamity threatening the few leading industries of the islands. The need of promoting greater agricultural diversification is becoming increasingly apparent. Continuous culture of one staple crop on a given area usually results in more rapid soil depletion and development of insect pests and fungus diseases than when an intelligent rotation of crops is practiced. Development of the culture of diversified crops and associated industries is especially important in Hawaii, where people of numerous nationalities and racial mixtures are making their homes. Not all of such a population are content to do the work provided by the comparatively few major local industries. A diversified agricultural program will make possible not only the more even distribution of labor throughout the year by opening new fields of specialized employment, but also the more complete utilization of many lands which are not adapted to the leading crops, thus rendering them contributory to the general economic prosperity of the islands.

The Pan-Pacific Conservation Congress, which met in Honolulu under the auspices of the Pan-Pacific Union from July 31 to August 14, 1924, emphasized the wisdom of following the policies advocated by the station in developing and promoting the diversified agricultural industries of the islands. E. W. Allen, chief of the Office of Experiment Stations, United States Department of Agriculture, a delegate to the congress, made a thorough inspection of the work of the station and gave careful consideration to its various problems.

Some changes in the station boundaries were made during the year. An area aggregating 83,588 square feet (approximately 1.92 acres) near Magazine Street, Honolulu, was transferred to the Territory by order of the President dated December 22, 1924; and two tracts of land, aggregating 0.784 acre, on the slopes of Tantalus, near Honolulu, and originally a part of the station reservation, were transferred to the Territory by order of the President dated January 13, 1925. Through an executive order of the governor dated June 15, 1925, the station received from the Territory a tract of land totaling 0.636 acre on Tantalus, together with the buildings thereon, in connection with a boundary adjustment agreement negotiated in July, 1924. The station also obtained from the commissioner of public lands, Hawaii, authority to use the land occupied by the Haleakala demonstration farm, Maui.

The development of vegetative methods of propagation, which are not only very successful but also so simple as to be readily used by nurserymen, is one of the outstanding achievements of the horticultural division. Commercial orchard development depends for success upon vegetative methods of propagation, since many of the tropical fruits fail to come true to seed. A total of 62 accessions of new and rare economic plants was made during the year to test their adaptability to Hawaiian conditions, and approximately 30,000 plants, young trees, and packages of station-grown seed of improved varieties were distributed to growers in all parts of the Territory and elsewhere. The horticulturist acted as one of the judges in the school-garden contests, making four trips to each of 38 gardens for the purpose.

The work of the agronomy division was directed principally to solving problems dealing with food and forage crops and poultry management, and to cooperation with the extension division in the boys' and girls' club work. In October the agronomist acted as associate poultry judge at the Maui County Agricultural Fair, and as secretary of the poultry show at the Territorial fair, held at Honolulu October 20 to 25, inclusive. The agronomy division had exhibits at both fairs. Accompanied by the executive secretary of the Hawaiian Homes Commission, the agronomist inspected the Molokai homestead lands, which are being opened to native Hawaiians and are thought to have great diversified agricultural possibilities. He also cooperated with the Hawaiian Homes Commission in furnishing improved planting material and crops to homesteaders.

The chemical division confined its efforts principally to solving technical problems arising in connection with the edible canna starch industry, and the preservation of Hawaiian fruits and fruit products. Cooperative work with local manufacturers of preserved fruits was continued, and analyses were made of a large number of varieties of locally grown vegetables, including many of oriental origin.

The extension agent for the island of Hawaii, in addition to his other duties, assisted farmers in working out rational cropping systems, and obtaining improved varieties of plants and seed, and aided in marketing their crops. He also distributed trees for windbreaks, as well as seeds and bulletins; loaned newspaper articles dealing with agricultural topics to various homesteaders; gave advice concerning cultural and fertilizer requirements for the most profitable production of crops; devoted considerable time to boy scout activities; acted as

leader in the boys' and girls' club work and as chairman of the agricultural section of the county school fair; and visited as regularly as possible farmers in the different parts of the island. He traveled approximately 11,000 miles, visiting when possible each section once a month, and readily accessible localities more frequently. He also acted as middleman between homesteaders and various sources of agricultural information desired by them.

The superintendent of the Haleakala demonstration farm devoted a small part of his time to county agent activities, and the rest to work on the farm. The Haleakala demonstration farm serves as the distributing center for propagating material of improved food and forage crops, and is conducted to determine and demonstrate what kind of crops can be produced on and the cultural practices best adapted to that part of the island in which the farm is located. Approximately 2,000 feet of new fencing was built at the farm, and about 100 feet of water pipe was changed to permit cultivating what would otherwise be waste ground. The original buildings were made more nearly rainproof than formerly, and a chicken house 7 by 14 feet was erected. The guava, lantana, and pamakani (*Eupatorium glandulosum*) were cleared from the gulch on the north side of the farm to permit use of the ground for pasture.

Boys' and girls' 4–H clubs were organized and conducted on the islands of Oahu, Maui, Hawaii, and Kauai, and new enrollments and some reenrollments were made in the communities doing club work last year, and also in Schofield, Oahu; Lahaina, Maui; and Kapaa, Kauai. Eight new communities were formed on the island of Hawaii. In addition to supervising 38 clubs in Oahu, with an enrollment of over 700 members, the club leader made three visits to Maui and two to Hawaii during the year. About 70 per cent of her time was given to field work, making personal visits to club members, attending club meetings, and promoting club interests, and the rest was devoted to office and demonstration work at the station. The club enrollment in Hawaii was more than double that of last year. A total of 1,460 children enrolled, with 1,095 members, or 75 per cent, reporting.

REPORT OF THE HORTICULTURAL DIVISION

By W. T. Pope

VEGETATIVE PROPAGATION EXPERIMENTS WITH TROPICAL FRUITS

Failure to learn how to propagate fruit trees successfully by vegetative methods is probably one of the greatest hindrances to a more rapid development of the fruit industry in Hawaii. It is estimated that local nurserymen or growers bring an average of less than 15 per cent of their good standard varieties of tropical fruit trees to the proper size and condition for marketing to prospective growers. As a result they are compelled to ask a much higher price for the trees than would be obtained were a larger number of the grafts successful. With budded avocados and grafted mangoes selling at $4.50 each, 2-year-old breadfruit trees at $6, and air-layered litchi trees of a good variety at $25 each, very few are going into the business of fruit growing. Asexual methods of propagating some of the more important tropical fruits worked out by the station are giving very gratifying results.

AVOCADOS

In July and August, 1924, some 1,300 avocado seedlings were grown in gallon tin containers to furnish necessary rootstock material for budding and grafting experiments. The methods used included whip grafting, side-tongue grafting, and shield budding. Of the three the whip-graft method, utilizing very young growth, proved to be the most satisfactory. (Fig. 1.) The stock and scion materials are more readily obtained for this method than for the others, and the trees can be set in their permanent places before the roots become pot-bound. Trees of proper size for setting out can be produced in six months after the seed has been planted, or five to nine months earlier than under the old methods. A better union

FIG 1.—Whip-grafted avocado trees ready for setting out, 146 days after germination of seed for stock

is obtained and a larger number of successes result when early growth is used. Over 60 per cent of successful grafts have been made with the Macdonald variety of avocado.

The side-tongue method of propagating avocado trees is adapted to seedling stocks over 6 months old. The scion and the stock should have reached the same stage of maturity, and even then may fail to unite perfectly. The side-tongue method, notwithstanding its disadvantage, has been found to be superior to shield budding, the heretofore most commonly practiced method of propagating avocados. Shield budding is at best a very slow method of propagation, especially when the seedlings are grown in tin and other containers, as must be done in most parts of Hawaii. Bud wood is rather hard to find during the "flushing" period of the seedlings. Budded trees are often difficult to straighten properly before they

are set out, and usually are difficult to sell. However, they usually straighten of their own accord during the first years of growth.

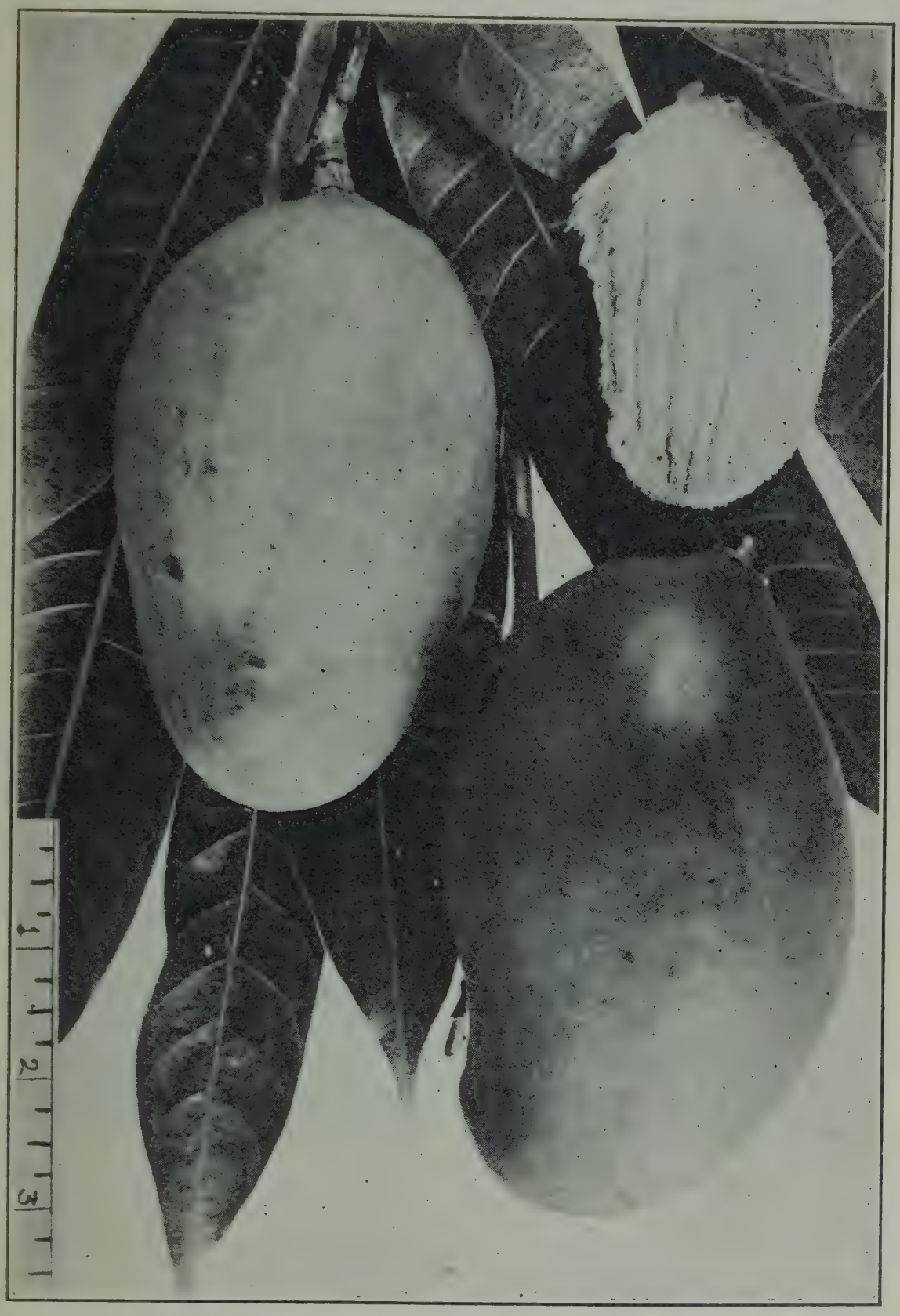

FIG. 2.—The Victoria, one of the best mangoes for general culture in Hawaii. The skin is a brilliant red and resistant to the fruit fly

MANGOES

The side-tongue method of grafting, as previously worked out at the station, was repeated with a number of selected varieties of the mango, including the Victoria, Pirie, Mulgoba, Alphonse, Whitney,

Wootten, and Kalihi. The Victoria, a vigorous and prolific yielder of excellent fruit, is a general favorite among growers (fig. 2), and is not subject to attack by the Mediterranean fruit fly. Seedlings of the sturdy Hawaiian mango were grown from seed in gallon containers and kept growing vigorously for 8 to 12 months, when they are of suitable size for grafting. (Fig. 3.) The satisfactory results obtained again confirm the value of the side-tongue method of grafting for mangoes under Hawaiian conditions.

FIG. 3.—Grafted Victoria mango tree 2 years of age, with 42 fruits

GRAPES

Promising varieties of grapes were received from various local growers during the year, and a number of new varieties were propagated from cuttings received from California. Of 16 varieties which were successfully grafted on 3-year-old Isabella rootstocks in January, 1925, Lisbon, Jakea, and Campo Alegre came into fruit in June, 1925. Scions of the Scuppernong and another variety of the Muscadine type failed to unite with the Isabella variety. Root cuttings of Isabella

grapes growing in gallon containers were successfully grafted with a number of different varieties, and plants grown from seed introduced from southern Georgia are making excellent growth.

BREADFRUIT

Methods of propagating seedless breadfruit trees from surface roots have been under test at the station since 1921. Each year the tests yield additional information, which is making possible the production of a greater quantity of propagating material. The rooting and sprouting of cuttings is a slow process, and even after the young trees are a foot high they may fail to survive transplanting from the propagating bed. It has been found advisable to maintain them in the propagating bench until they are considerably more than a foot high. This is done by underlaying the 6-inch layer of coral sand in the propagating bed with a 4-inch layer of rich, loose soil. The soil contains a greater amount of available plant food and will stimulate root growth and prevent the stunting which usually occurs when the cuttings are grown in coral sand alone. If the young trees are potted off in soil some time before transplanting, the roots will become sufficiently well established to withstand open-ground conditions. A number of root cuttings of different varieties, obtained from the Society Islands, south Pacific Ocean, are being propagated in the same manner as the Hawaiian variety.

The breadfruit tree is highly ornamental and should be grown in every garden. A single tree will often produce sufficient fruit for the average family during six or eight months of the year. Heavy demands were made upon the station for the trees, but distribution of surplus material was confined to experimenters working in cooperation with the station.

LITCHI

Several of the litchi trees in the station orchard have reached sufficient size for air layering. In October, 1924, some 14 branches, each 4 or 5 feet long, in the tops of litchi trees were scarred where it was desired to have roots start. On the following day the wounds were surrounded with masses of soil held firmly in place by wide burlap bands and galvanized poultry wire. A gallon container filled with water and having an opening in the bottom to permit a slow drip was suspended above each mass to keep it moist. After five months the branches had established root systems and were severed from the trees and set in tubs filled with soil. (Fig. 4.) This method, although not entirely new in Hawaii, is proving very successful as a means of rapidly propagating the litchi. Air layering has long been employed in China and undoubtedly is far superior to inarching, grafting, or budding, none of which has been successful at the station.

SEED PROPAGATION OF TROPICAL FRUITS

It is necessary to rely on seedlings in much of the propagating work. The advisibility of using only selected seed has been strongly confirmed in the work of the station. Good seed is especially important in the improvement of annual plants, such as the tomato and

the roselle. The work on the production of perennial stock plants on which to bud or graft choice varieties of fruit, such as the mango, avocado, or citrus, indicates that selected seeds of certain varieties or species produce more vigorous trees and give better unions than do those of other varieties. Rootstocks from the seed of the sturdy Hawaiian mangoes, for instance, are often superior to seedlings grown from the seed of improved imported varieties. Both oranges and lemons may be grafted into many species of citrus stock, but they are found to be more vigorous and productive when united to certain species, as, for example, the sour orange in preference to the rough lemon.

HYBRIDIZATION EXPERIMENTS

Cross-pollination experiments were made during the year in connection with tomato and papaya breeding. Several hundred tomato

FIG. 4.—Setting air-layered branches of litchi tree in tubs for further root development before planting in the orchard

crosses were made, and seedlings from the more desirable types have already been obtained. Crosses were also made between papayas of different types to determine to what extent the fruit of the tree of one type may be influenced directly by pollen from a tree of a different type.

MISCELLANEOUS INTRODUCTIONS

Among the introductions of the year were 25 specimens of Pejibaye palms (*Guilielma utilis*) from Central America, received through the Office of Foreign Seed and Plant Introduction, United States Department of Agriculture, plants of yerba maté (*Ilex paraguayensis*), root cuttings of 18 varieties of breadfruit from the South Seas, as well as propagating material of 8 varieties of grapes. Seed of the jaboticaba (*Myrciaria* sp.) from Pernambuco was received, but it did not arrive in a viable condition. A number of other plants received from local cooperators and not under test for several years

included 3 varieties of annonas, 2 of the cashew nut, 4 of bananas, and several varieties of mangoes, avocados, citrus, and granadilla. The Pejibaye palms are doing so well as to indicate the establishment in Hawaii of this valuable species, the fruit of which is edible. Vigorous plants of durian (*Durio zibethinus*) and rambutan (*Nephelium lappaceum*) have developed from seeds received from the botanical gardens of Buitenzorg, Java. A single tree of the durian, an early introduction, has fruited in Hawaii, but the fruit is not generally known locally. The rambutan is of Malayan origin and is very extensively used elsewhere in the Tropics, but is new to these islands.

HORTICULTURAL EXTENSION WORK

Not infrequently the horticultural division is visited by students and others who are interested in some branch of its work. Every effort is made to stimulate interest in work of a horticultural nature, and demonstrations are given so that the visitors may learn the proper methods. In many instances the students are given the opportunity to put into actual practice the instructions given. A number of exhibits were made at fairs and other gatherings where illustrative material was used to disseminate agricultural information. On these occasions the horticulturist emphasized the need of using station and Department of Agriculture publications dealing with improved methods of culture and pest control.

DISTRIBUTION OF SEEDS AND PLANTS

Approximately 30,000 plants and packages of improved station-grown seed were distributed during the year to growers in different parts of the Territory, and to some on the mainland and elsewhere. Seed and plant distribution as practiced by the station serves as a stimulus to a more rapid development of Hawaiian horticulture. It creates a greater demand for plants and causes them to be grown by people who would hardly do so were a cash outlay involved. It also brings to the attention of many people the important work in plant improvement which the station has under way, and gives the station the benefit of numerous cooperative experiments over a wide range of conditions.

REPORT OF THE AGRONOMY DIVISION

By H. L. Chung

CORN

The new variety of sweet corn which the station originated by crossing the Henderson sweet with a white Guam corn, has well-fixed characters and combines the color and wrinkled kernels of the former with the stalkiness and leaf-hopper resistance of the latter. A large quantity of the seed of this new variety was distributed.

Golden Bantam, another sweet variety, is proving popular, but has the disadvantage that it it can not be grown in localities where the corn leaf hopper is present in abundance. Work was undertaken to develop a variety proving resistant to leaf-hopper attack and having a sturdy stalk. A yellow strain of Guam corn resulting from a cross between Guam corn and Cuban Red was pollinated with Golden Bantam for this purpose. Seeds obtained from the cross will be used for further work.

TARO

Taro problems are becoming increasingly important as the natural habitat of the crop is being used for other purposes. Land values near the city of Honolulu, Oahu, have increased considerably, and the rentals asked for taro areas in the vicinity have correspondingly increased. As a result many of the taro-growing lands are no longer used for that purpose. Ordinarily these abandoned areas are sold for home sites. Realizing that under these circumstances dry-land taro is likely to play an important rôle in the agriculture of the islands, the agronomist obtained from Thomas White, of Kona, Hawaii, a large collection of promising dry-land varieties to determine their relative physical characteristics, drought-resistant ability, and adaptability to various types of soil. A collection of both wet and dry-land taro tops was also received from American Samoa through the courtesy of E. M. Ehrhorn, chief plant inspector of the Territorial Board of Agriculture and Forestry, Honolulu. The taro tops are reported to be from varieties of the Mammoth type. The wet-land varieties are being tested in a specially prepared aquatic area in the agronomy field.

EDIBLE CANNA

Edible canna investigations were confined to cultural tests made to learn the effect of green manuring and close planting on the yield of tubers.

SWEET POTATOES

The large collection of sweet-potato hybrids resulting from crosses made in 1924 was considerably reduced in number. Many of the seedlings showed undesirable features and were eliminated at harvest time, and others were discarded because they failed to prove superior to the standard varieties when cooked.

Approximately 60,000 sweet-potato cuttings of improved varieties were distributed during the year. A large number of the cuttings were sent to homesteaders on Molokai.

WHITE POTATOES

A potato variety of the Hamakua strain is proving well adapted to the lowlands of the islands. In addition to being a good producer, it is a much better keeper than the original Hamakua variety and has tender skin and very conspicuous lavender-colored eyes. Stock for further tests and distribution is on hand for next season's planting.

LETTUCE

The erroneous local belief that head lettuce can not be successfully grown in Hawaii has resulted in importation of large quantities of lettuce from California. Lettuce can be found throughout the year in many of the Japanese vegetable stalls, to which it is brought by Japanese truck gardeners from Waimea, Hawaii, and other cool regions of the islands. A series of variety tests with head lettuce was made during the year, and 6 of the 15 varieties originally tested were retained. However, the varieties and individual plants selected varied considerably in degree of solidity of the heads. The best individual plants were retained for further breeding work.

FORAGE GRASSES

Approximately 50,000 cuttings of Napier grass (*Pennisetum purpureum*) and Merker grass (*P. merkeri*) were distributed during the year. Both grasses are in great favor with poultrymen, cattlemen, and draft-horse owners. Merker grass has undergone a great change through careful selection. Of the two distinct types established, one has very thin stalks and is suitable for green feed for poultry, whereas the other has thick and rank-growing stems and is adapted to cattle and horse feeding.

A demonstration area devoted to different species of grass is maintained in one of the agronomy fields, and the yield is noted at each harvest. Guatemala grass (*Tripsacum laxum*) has so far proved to be well adapted to areas of limited rainfall. Each season the plants produce fertile seeds, which are distributed to Hawaiian ranchers for test. Tunis, Sudan, and Wonder Forage grasses, found to be affected with the mosaic disease, are being studied by the pathology division of the Hawaiian Sugar Planters' station with reference to transmission of the mosaic to seedlings from seeds of diseased plants.

DISTRIBUTION OF SEEDS AND CUTTINGS

A large quantity of seeds and cuttings was distributed. Cuttings of various kinds of grasses formed the bulk of the distribution for forage purposes, and sweet potatoes, corn, lettuce, and edible canna were most largely distributed for human consumption.

Many of the experts who attended the Pan-Pacific Conservation Congress from July 31 to August 14, 1924, were supplied upon request with seeds and cuttings of the more promising economic plants, especially those adapted for green-manure purposes.

POULTRY INVESTIGATIONS

Sorehead and roup of poultry, which have been prevalent throughout the islands, continued to receive attention. Other poultry troubles reported to the agronomist included bumblefoot, atrophy of the liver, canker, and intestinal worms.

REPORT OF THE CHEMICAL DIVISION

By J. C. Ripperton

EDIBLE CANNA INVESTIGATIONS

During the year the chemist visited a number of cornstarch manufacturing concerns on the mainland to learn to what extent their methods might be applicable to edible canna starch making in Hawaii. Manufacturers of standard types of washers, shredders, extractors, purifiers, and driers were also consulted as to the possible adaptability of their machines to the product. A series of samples of canna starch prepared from factory runs on a large scale, using different procedures in the manufacturing process, was submitted to a number of textile plant directors, dextrin manufacturers, starch brokers, and the like for the purpose of obtaining information on the manufacturing process and to determine to what general uses edible canna starch might be adapted.

METHODS OF STUDY

Every effort was made to devise methods admitting of continuous study of the growth of edible canna on the various experimental plats both at the central station and at Waimea, Hawaii. Some of the more important features of the work include (1) classification of tubers, the lot from each hill being grouped as dormant, mature, immature with stalk developing, or immature with undeveloped stalk, depending upon the appearance of the stalk; (2) genealogy of tubers, which are divided according to successive generations, beginning with the original tuber; (3) determination of the reducing and nonreducing sugars in the expressed sap of the tubers and stalk; and (4) determination of the specific gravity of the tubers.

METHOD OF GROWTH

A study was made of the lateral, longitudinal, and apical growth of individual tubers as well as of the deposition of starch in the storage cells after growth of the tuber had ceased. The fact that a very large part of the growth of any tuber comes from the parent plant and not from its own stalk emphasizes the importance of the early stalk growth of the hill upon subsequent storage of starch. The common observation that a hill of canna gradually "runs out," the new growth producing tubers decreasing in size until they ultimately become undesirable for starch making, has led to a study to learn whether this phenomenon is due to physiological influence or such external influences as soil packing and lack of aeration.

FIELD EXPERIMENTS

Edible canna was grown on a field scale at the station, and classifications of hills were made each month, beginning with the twelfth month after planting and extending through the twenty-second month. Studies were made of the effect of planting at different depths on manner of growth, and of varying the quantities of irrigation water on the growing crop. A total of 15 acres is now under cultivation at Waimea, Hawaii, in cooperation with a private starch-manufacturing concern and the extension agent on Hawaii. (Fig. 5.) Homesteaders are showing considerable interest in the experiment, which includes the best time of applying fertilizers to canna, tuber selection for planting, the effect of spacing and depth of planting on yield of tubers, and the feasibility of mulching with canna tops. Monthly harvests from 9-month-old crops were begun on 2 one-tenth acre plats to be carried through to the eighteenth month from planting to learn the best age at which to harvest the crop. Another experiment was begun on 42 one-tenth acre plats to determine the fertilizer formula best suited to the crop.

VARIATION IN CHEMICAL COMPOSITION

As has been previously noted,[1] the chemical composition of individual tubers within a single hill is subject to wide variation, due primarily to the continuous growth of the hill, the tubers within it varying in age from developing buds to full-grown dormant tubers.

[1] Hawaii Sta. Bul. 54, p. 8; Edible canna in Hawaii.

Further studies were made of these variations correlated with the above-outlined investigations of the methods of studying the growth of the plant.

The nature of the sugar formed by photosynthesis in the leaves was determined, as well as the changes occurring during translocation

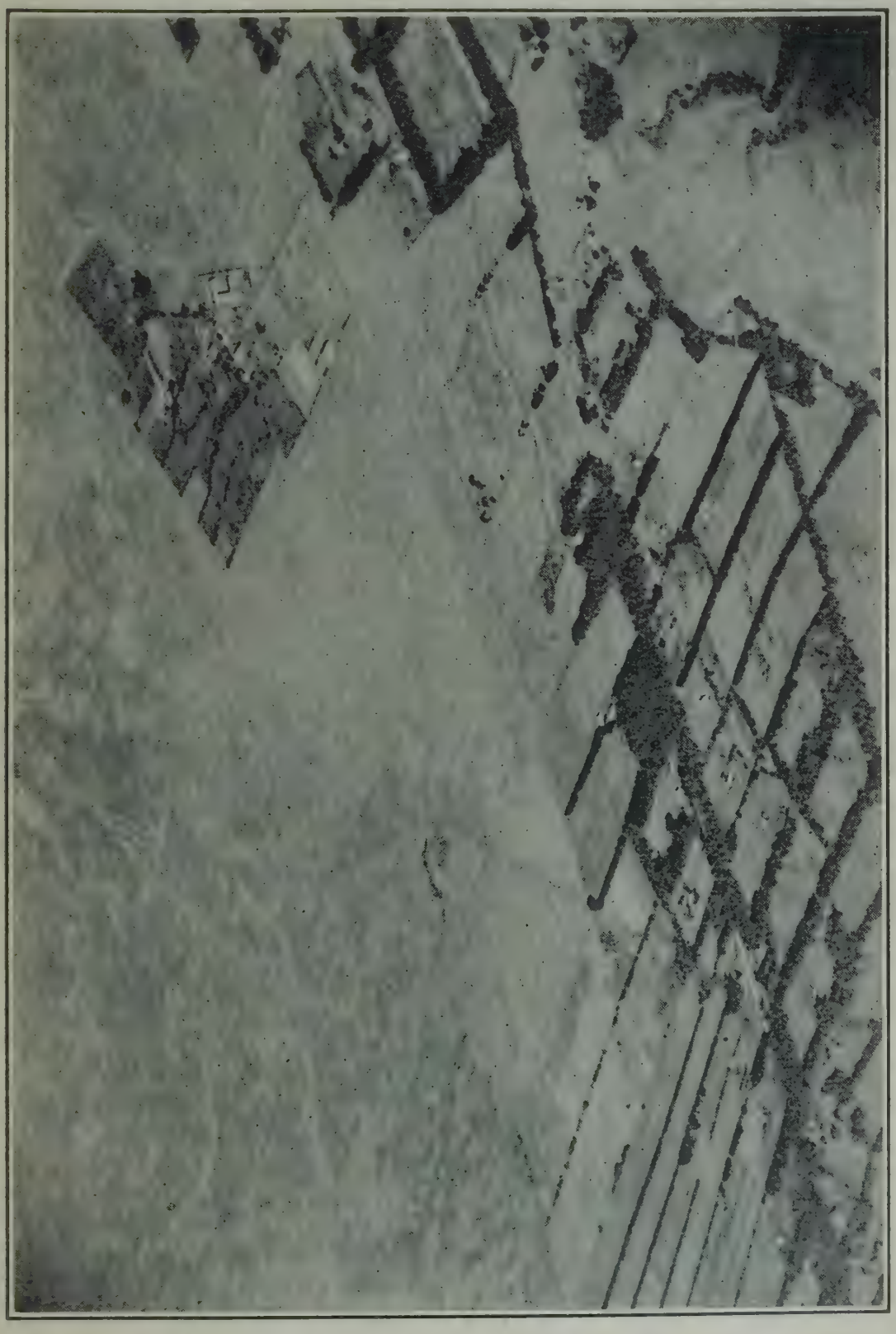

FIG. 5.—Aerial view of the Waimea homesteads where edible canna is now being grown for its starch. In the foreground is grazing land which ultimately will be available for canna production. The climate and soil of this district make it ideally adapted to this crop. Note the general use of windbreaks. (Courtesy of the eleventh photo section, Luke Field, U. S. Army, Hawaiian Division)

of the sugar through the sheaths and stalks to its storage in the tubers as starch. The determination of the sugars in connection with the classification and genealogy of the hill as a means of estimating the rate of growth of the plant is a promising method. Sap samples from

plants in the various experimental plats were collected at intervals for analysis, and other components of the plant sap were also investigated. Of special importance with reference to the manufacture of starch is the slimy precipitate, which settles out and intermixes with the upper stratum of starch and renders purification and sedimentation difficult when the process is delayed. Studies were made of the nature and causes of the precipitate, and the methods devised for preventing it are being tested in connection with the commercial purification of the starch.

Microscopic studies were made of the morphological characteristics of the starch in the stalk and in the different parts of the tuber. The granules were found to vary considerably in size, depending upon their location in the plant. This fact would seem to be of importance from the commercial standpoint. Determination was also made of the starch in the leaves, sheaths, and stems in connection with the carbohydrate metabolism of the stalk. The percentages of actual starch in the tubers of different ages, classes, and generations were determined by the diastase method. These determinations, coupled with the specific gravity determinations, should make possible the construction of a table enabling the chemist to estimate quickly the approximate starch content of a lot of tubers in the field or factory.

Determinations of the principal ash constituents of the canna plant were begun to learn its mineral requirements at different stages of growth.

POSSIBLE USES OF THE STARCH

Samples of edible canna starch were submitted to a number of industrial starch users who are interested in the product. The starch seems to have potential possibilities for commercial purposes, if it can be produced at a price sufficiently low to permit its competing successfully on the market with potato, cassava, and sago starches. Because of the lack of standard laboratory methods of evaluating a starch or accurately determining its properties, it will hardly be possible to learn to what extent edible canna starch can be used until factory runs on a large scale are made in the various industries. Samples of commercial starches were procured from the mainland to compare their merits with those of the edible canna starch. The comparisons should show the general nature of the uses to which edible canna starch may ultimately be put.

PRESERVATION OF HAWAIIAN FRUITS

A special study was made of the kinds of machinery and methods used by various fruit-preserving concerns on the mainland, and samples of jellies, jams, and conserves from locally grown fruit were submitted to wholesale dealers for suggestions as to their salability and improvement. The poha, guava, and pineapple jams and marmalades were received with special interest by the mainland concerns. Efforts are under way to develop a profitable mainland market for these fruit products. Cooperative work with a local company was continued, the chemical division rendering general assistance in testing fruit juices, standardizing fruit products, and emphasizing the need of employing up-to-date methods and machinery in the manufacture of fruit products. (Figs. 6 and 7.)

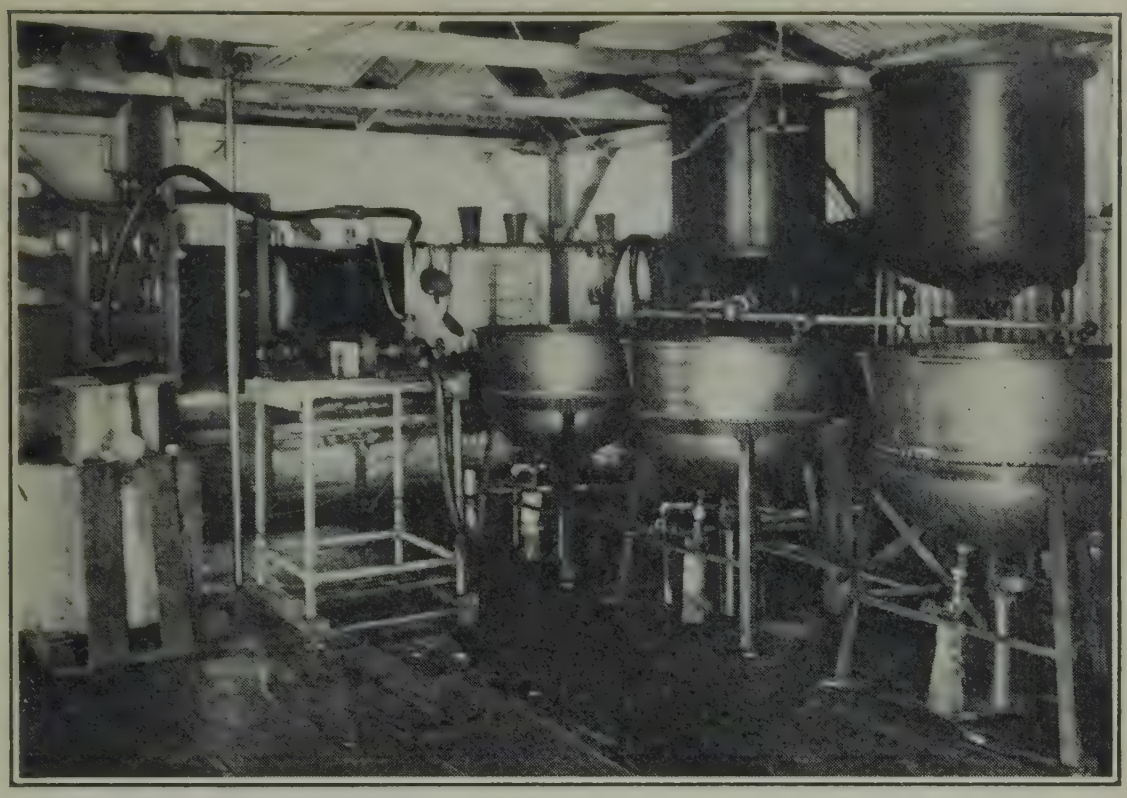

FIG. 6.—Interior of a modern fruit-preserving plant in Hawaii, showing the large steam-jacketed copper boiling kettles and above them the glass-lined storage tanks

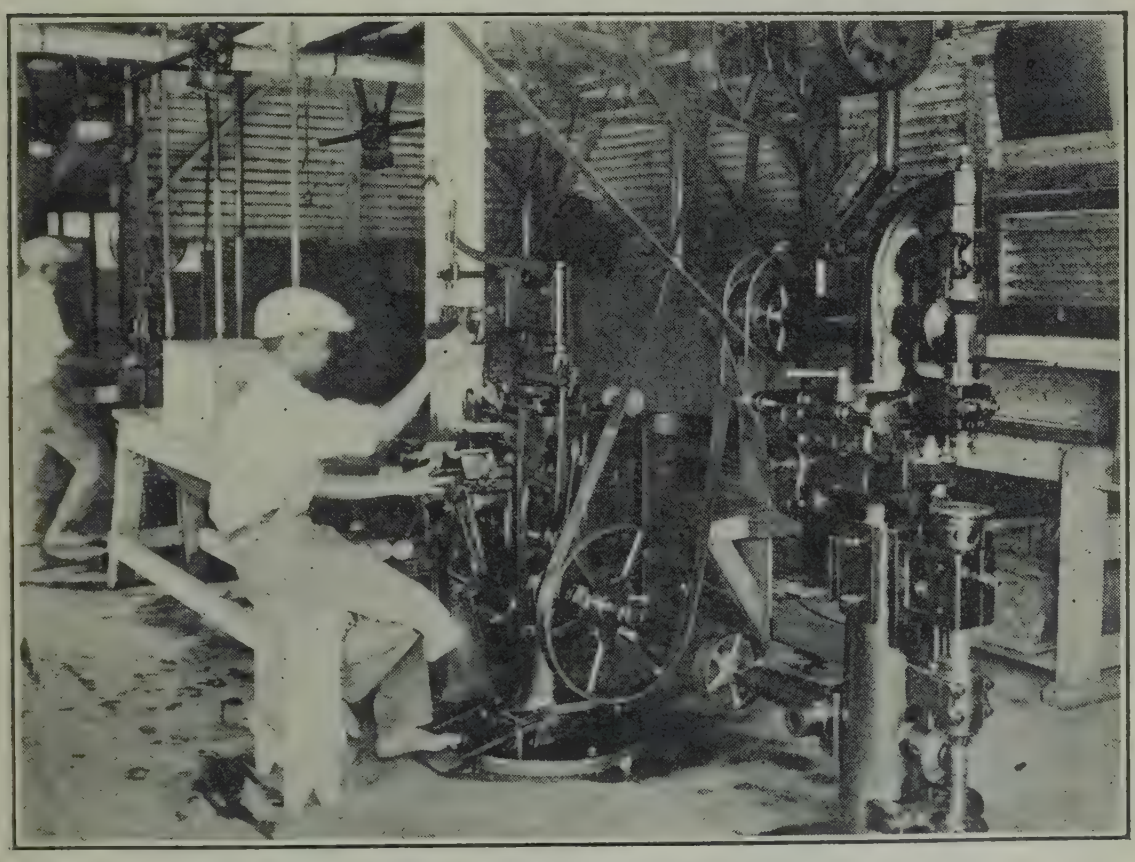

FIG. 7.—Modern machinery used in filling, capping, and labeling

COMPOSITION OF HAWAIIAN-GROWN VEGETABLES

Completion of the tri-local vegetable experiment undertaken to compare the mineral constituents of Hawaiian and mainland grown vegetables was postponed because of crop failures in one of the localities under test. Analyses were begun of a series of 45 different Hawaiian-grown vegetables collected by the agronomist of the station, and will include determinations of their nutritive constituents as well as of calcium, phosphorus, iron, and alkalinity of ash.

HALEAKALA SUBSTATION AND DEMONSTRATION FARM

By H. F. Willey

FORAGE CROPS

Pigeon peas.—About 6 acres were planted with pigeon peas at the Haleakala substation and demonstration farm in September, 1924. Merker and Napier grasses were planted between the rows of pigeon peas in half the field, and various smaller tame grasses between the rows of the other half. The area is later to be used as a pasture for milch cows. A 2-acre field on which tame grasses were interplanted with pigeon peas was used as a hog pasture. The grasses made excellent pasture, but many of the pigeon peas were wasted in the efforts of the larger animals to get at the pods. Pigeon peas are also being grown on a half-acre plat for the production of seed for distribution to interested farmers. It is impossible at times to supply the demand for pigeon-pea seed. On account of the peculiar climatic conditions prevailing in this region the crop produces seed under difficulty, many of the pods becoming moldy before drying sufficiently to shell.

Purple vetch.—Purple vetch, planted in September, 1924, is in excellent condition and makes one of the best cover crops available. The crop has proved its efficiency as a weed destroyer at a mountain summer home at an elevation of 3,500 feet.

Cultivated grasses.—Of eight varieties of grasses planted during the year, Harding, orchard, perennial rye, Rhodes, and Smilo grasses withstood adverse weather conditions very well and made excellent pasture. Merker and Napier grasses again demonstrated their value as soiling crops, and the Harding variety proved to be one of the most valuable pasture grasses tried, the high cost of seed being its only handicap.

Sorghum.—Ratoon crops of kafir and Egyptian corn, feterita, and milo were harvested at intervals of about two months. After the fourth cutting the crops made stunted growth and the heads failed to fill well.

ROOT CROPS

Cassava.—Twenty hills of Cassava were harvested in early May, yielding on the average about 10 pounds of roots to the hill 10 months after planting. Seventy-five cuttings were planted May 29, 1925.

Edible canna.—Harvested May 8, 12 months after planting, edible canna yielded on the average 10.5 pounds of tubers to the hill. No greater yield was obtained in the school gardens at lower altitudes, from which it is concluded that the high altitude of the demonstration farm does not seriously affect growth. The boarding schools of Maui

are using edible canna tubers as a substitute for white potatoes. During May, 1925, about 50 pounds of the tubers were planted.

Taro.—Of 10 varieties of dry-land taro which were harvested in early May, Mana Ulaula, Mana Eleele, Iaia, and Lehua gave good results. Another planting of these varieties was made May 30.

Sweet potatoes.—Twenty varieties of sweet potatoes were planted in small plats, and some of the most prolific varieties in large plats in May. Thousands of cuttings of the leading varieties, including Tantalus, Haleakala, Madeira, Yellow Yam, Delicious Yellow, Native Red, and Huamoa, have been distributed on Maui for use as a stock feed and for human consumption.

White potatoes.—The varieties Red Rose, White Rose, British Queen, and Burbank were harvested November 14, yielding a crop only equal to the quantity of seed planted. After the ground was plowed it yielded a volunteer crop proving better than the original, apparently because of the more favorable weather conditions.

VEGETABLES

Squash.—Approximately 400 fruits of a Vegetable Marrow variety were harvested in November and December, and largely used as a hog feed. Another planting of the same variety made in February failed to produce a crop.

Pumpkin.—About 100 pumpkins of the Jack O'Lantern, Mammoth King, and Boston Pie varieties were harvested in November and December for table use and as a hog feed.

Radishes.—Of four varieties of radish planted in February, White Icicle and French Breakfast made the best growth. Crimson Giant and Long Scarlet Short Top grew slowly, were pithy, and had a biting taste.

Carrots.—The varieties Oxheart, French Forcing, Danvers Half Long, and Long Orange are growing slowly as a result of cool weather.

Peas.—Of the four varieties of peas, Telephone, American Wonder, Stratagem, and Bellingham, planted in February, the last two named were the only ones to succeed. A second planting made in May was in excellent condition by June.

Beans.—Twelve varieties of beans were planted in February, but were killed by the cold, wet weather. The varieties Kentucky Wonder, Davis Kidney Wax, Lazy Wife, Stringless Green Pod, and White Seeded Kentucky Wonder, planted May 14, were in excellent condition by June 30.

Lettuce.—The varieties California Cream Butter, All Seasons, May King, and Immensity, planted in February, were killed by heavy rains. A second planting made May 16 is doing well at this writing (June 30).

Tomatoes.—The Dwarf Stone variety of tomato was harvested during July, August, and September. Fifty plants yielded approximately 20 bushels of smooth, ripe fruits, and 3 bushels of green fruits which were used for pickling and relishes. The New Stone variety bore very heavily, but most of its fruit rotted at the stem end and dropped prematurely from the vine. A few plants of the Haleakala and John Baer varieties, which have already established their reputations at the farm, were grown as a basis of comparison. Ponderosa, Chalk's Early Jewel, John Baer, Haleakala, Dwarf Stone, and New Stone

were planted in February, but failed to thrive because of unfavorable weather. Another planting of the same varieties made in May is doing well.

Watermelons.—Watermelons of the Kleckley Sweets variety were planted in February, but were killed by cold rains.

FRUITS

A number of fruit trees were planted in November, including those of the mulberry, star apple, mango, avocado, pomegranate, soursop, fig, and papaya. All are growing except the papaya. Plantings previously made are growing very slowly.

Pineapples.—The second crop of Smooth Cayenne pineapples, planted without paper mulch in October, 1922, was in bloom June 1. The plants have good color and give promise of yielding a fair crop. Pineapples planted in June, 1923, under paper mulch, averaged 3¼ pounds from unfertilized and 3¾ pounds from fertilized plats. Fifty acres on an adjoining ranch are being planted with pineapples, apparently as the result of the showing made by the early plantings at the farm.

Strawberries.—The variety New Carolina has been grown for three years. The crop ripens slowly, but the fruit is large and abundant. The demands for the plants were very heavy. Some of the homesteaders who received plants from the farm last year are now marketing their berries at 50 cents a pound.

MISCELLANEOUS PLANTINGS

Peanuts.—The Cuban and Valencia varieties of peanut were harvested in November. One pound of the Cuban seed yielded 17 pounds of peanuts, and 5 pounds of the Valencia 95 pounds of peanuts. The climate is unfavorable to production on a commercial scale, causing the crop to mold before it can be dried.

Broomcorn.—The varieties A and M Dwarf, Standard Dwarf, California Golden Standard, Acme, and Whisk Dwarf were harvested in July. The second crop was harvested in October, and the third the following January.

Trees for windbreaks.—Of 1,200 eucalyptus trees (*Eucalyptus robusta*) planted in January, only 800 survived the unfavorable weather. Eucalyptus trees planted in 1922 are now between 25 and 30 feet high and are forming an efficient windbreak along the north side of the farm.

Field corn.—Nine varieties of field corn, harvested from 12 acres of land between October 15 and November 15, yielded an average of approximately 25 bushels per acre. The best of the seed was selected for further work, and the rest was fed to the farm stock. The varieties Bloody Butcher, Haleakala, Indian Squaw, Calico, Kula, Red Flint, and Guam were planted in February, most of them being fertilized with bone meal. The early growth of the crop was excellent, but the later growth was seriously affected by the cold rains which set in shortly after planting.

Pop corn.—Both pearl and yellow varieties of pop corn were grown during the year. The pearl is by far the best. It yielded over 100 pounds of shelled corn from 1 pound of seed planted.

DISTRIBUTION OF SEEDS AND CUTTINGS

Propagating material was distributed during the year, as follows:

TABLE 1.—*Propagating material distributed during the fiscal year ended June 30, 1925, Haleakala demonstration farm*

Crop	Seed	Cuttings	Tubers	Plants
	Pounds	*Number*	*Pounds*	*Number*
Pigeon pea	45			
Beans	10½			
Peas	6¼			
Broomcorn	1½			
Cowpeas	2½			
Pop corn	20¼			
Field corn	157			
Tomato	¼			
Edible canna			1,000	
Strawberry				1,525
Pineapple				175
Sweet potato		6,000		
Napier and Merker grasses		7,000		

LIVESTOCK

The farm keeps a registered Holstein bull and a purebred Duroc-Jersey boar for community service. It also has 4 milk cows, 4 calves, 2 mules, 1 saddle pony, 7 brood sows, 4 pigs, and 100 chickens, for which green feed and part of the grain were raised on the farm.

RIDGING ATTACHMENT FOR USE IN PINEAPPLE FIELDS

An implement designed primarily for ridging up rows in pineapple fields, consisting of a combination of disks attached to a 5-tooth cultivator, was devised. It is already on sale in the local market, and is being used by a number of pineapple growers.

AGRICULTURAL EXTENSION WORK

Considerable time was devoted to the boys' and girls' club work at the local schools. The gardens showed an improvement over those of the previous year, and the pupils manifested considerable interest in the work. It is becoming very evident that the school is the place in which to start agricultural extension work. The Home and School Garden Fair, held at the Kahului fair grounds in May, proved that the youngsters can work. The superintendent acted as one of the judges at the fair and assisted the different schools in selecting their exhibits. He assumed the leadership of the Haleakala boys' and girls' pig club and helped the members in every possible way. Instruction was given in the best methods of feeding and handling the pigs, and grass cuttings were distributed for propagation. The superintendent also acted as a chairman of the committee for the boys' and girls' club at the seventh annual Maui County Agricultural Fair, and not only saw to it that the pigs were delivered at the fair grounds and properly exhibited, but also that the winners received the pigs awarded them as prizes.

REPORT OF EXTENSION AND DEMONSTRATION WORK ON THE ISLAND OF HAWAII

By R. A. Goff

Boys' and girls' clubs.—Boys' and girls' club work, including sewing clubs, canning clubs, pig clubs, poultry clubs, rabbit clubs, and garden clubs, was organized in 12 schools on the island of Hawaii, and a start was made in 6 other schools. Monthly meetings were held, and record books, Farmers' Bulletins of the United States Department of Agriculture, and other pamphlets of agricultural interest were distributed to members. The club in a body visited each home to observe the progress in club work, and many of the members entered exhibits at the country school fair, where ribbons and cash prizes were awarded the winners.

Hawaii school fair.—Vegetables from home and school gardens and field crops from demonstration plats in school gardens were displayed in the agricultural section of the Hawaii school fair held in Hilo May 15 and 16. The livestock section was larger than ever before, and was made up largely of pigs, chickens, pigeons, and rabbits belonging to members of the boys' and girls' clubs.

School and home garden work.—School and home gardens were visited many times during the year by the extension agent, and advice was given concerning the adaptability of various crops to the different localities and the best methods of cultivating the crops. The young gardeners were also assisted in obtaining seed and in marketing their products.

Assistance in boy scout activities.—The extension agent acted as scout commissioner for the island of Hawaii and as examiner for members desiring to qualify for agricultural merit badges. Examinations were held in agriculture, beekeeping, conservation, dairying, forestry, gardening, and poultry keeping.

Distribution of literature.—United States Department of Agriculture Farmers' Bulletins and circulars were distributed to boy scout troops at the posts for use in their libraries and as guides in preparing for examination for merit badges.

Extension of culture of the edible canna.—The potential possibilities of the edible canna for starch-manufacturing purposes and the adaptability of the crop to the Waimea district were deemed sufficient reasons for making experiments with the crop in that district. Waimea (2,600 feet elevation) is a wide, level valley between the Kohala Mountains and Mauna Kea. The rainfall of the district is plentiful and evenly distributed throughout the year, and the soil is such that where corn and potatoes can not be profitably grown edible canna can be produced. The ill effects of strong winds, which apparently are the only serious drawback to canna production in the region, can be practically overcome by growing windbreaks. Edible canna can be grown at elevations which are too high for sugar cane and pineapples, and on lands that are considered unadapted to anything but grazing. In view of the increasing demand for larger areas for edible canna production and the possibility of utilizing some of the thousands of acres of land which is now devoted to grazing in the Kohala, Kona, and Hamakua districts, it was decided to start experiments at different elevations to learn the adaptability of edible canna to various climatic and soil conditions. The crop is being

grown for 15-month periods in selected plats throughout the island. Part of each crop is to be harvested at intervals, beginning with the eighth month after planting, and records are to be kept of the growth and yields made. A rain gauge has been placed in each plat to show the amount and distribution of the rainfall.

The frequent though light rains of the Waimea district cause a luxuriant growth of weeds, which check the growth of edible canna unless horse cultivation and hand weeding are resorted to during the first five months after planting. This is an expensive process, and might well be dispensed with in favor of the use of arsenite of soda, which has proved a most efficient weed destroyer in cane fields. Fields receiving no horse cultivation, with little or no hand hoeing of the ratoon crop, gave consistently higher yields than did adjoining fields which were cultivated in the usual manner. An experiment was therefore undertaken in cooperation with the chemical division of the station to determine the relative yields and cost of cultivating two adjoining acres, using a poison spray on one and cultivation and the hoe on the other.

Extension of planting of fruit trees.—Seedling avocado and citrus trees were budded both at the nursery for distribution and on homesteads in different parts of the island. Special attention was given to establishing a sufficient number of avocado trees of different varieties which will bear during the winter months, so that the fruit may be available throughout the year

Extension of the use of the pigeon pea.—During the summer pigeon peas were planted in the school gardens to keep down weed growth and enrich the soil, and seed of the crop was distributed to all schools requesting it. A field of 100 acres at the Kapapala ranch in Kau was planted with pigeon peas and divided into paddocks to allow the crop to recover after having been heavily grazed. This plan is followed with great success on Maui, and should be more widely adopted than it is on Hawaii.

Grass demonstration and distribution work.—The experimental work with range grasses and forage crops carried on in cooperation with the Parker ranch in 1921 and 1922 was maintained, and areas in the Waimea and similar districts, where 12 of the varieties grew well and proved adapted to local conditions, were enlarged. Seeds, cuttings, and roots were planted in other sections of the ranch and also distributed to ranchmen, homesteaders, and dairymen throughout the island. One demonstration plat was maintained at the Konawaena School, in Kona, and another at Laupahoehoe, in Hamakua.

Planting windbreaks.—An effort was made to induce homesteaders to plant trees for windbreaks in parts of the island where crops are likely to be damaged by strong winds. The extension agent assisted the local nursery of the Board of Agriculture and Forestry to distribute seedling trees to homesteaders living in the more remote parts of the island.

BOYS' AND GIRLS' CLUB WORK

By Mabel Greene

Vacation clubs.—Six school centers conducted 12 4–H clubs in gardening, sewing, and handicraft during eight weeks of the summer vacation period, June 13 to August 14, and separate records were kept of the work done. The work was directed by 12 teachers, a man

and a woman who are specialists in vocational training and whose salaries were paid by the recreational committee of the board of supervisors being chosen for each center. Ruth C. Hoffman, primary supervisor of the Honolulu public schools, cooperated with the club leader in supervising the centers. The articles made by club members were placed on exhibition for sale in August and in November. Fifty per cent of the proceeds was given to members making the articles, and the rest was used to cover the cost of material and of plowing the ground for the gardens. The vacation clubs were successful from both an educational and a financial standpoint, and the work done by the members was complimented and indorsed by the board of directors of the Honolulu Chamber of Commerce.

Standard clubs.—The 81 standard clubs of the islands are distributed as follows:

FIG. 8.—4-H Sewing Club, showing graduation dresses made by members of the club

TABLE 2.—*Distribution of boys' and girls' clubs in Hawaii*

Club	Distribution				
	Oahu	Maui	Hawaii	Kauai	Total
Canning	2	2	1		5
Cane (sugar)			2		2
Flower			1		1
Garden	12	1	4	1	18
Poultry	4		8		12
Pig		2	3		5
Cooking	2		4		6
Bread making	2				2
Clothing	16	1	7		24
Rabbit			6		6

A number of local exhibitions were held in connection with the achievement day program. Interesting demonstrations were given in seed-corn testing by the Territorial Normal School, removing stains from clothing by the Needles and Pins Sewing Club, and a style show was conducted in which 24 girls wore self-made dresses for exhibition.

Club activities were carried on in cooperation with the Parent-Teachers' Association, the club division of the Young Women's Christian Association, the extension division of the station, and the Practical Arts' Club, which is composed of vocational teachers. Some extension work was done with a group of mothers of the Kakaako district of Honolulu through the Daughters of Hawaii Club and the club group of the Young Women's Christian Association.

Agricultural lantern slides were shown at various gatherings, and club songs and club yells were used as a means of keeping the young

FIG. 9.—Laboratory equipment, Pollyanna Canning Club

people interested in their work. Achievement pins were awarded where the making of graduation dresses formed a part of the clothing club work of the school. (Fig. 8.)

Club sales were made by the Pollyanna Club, and the canning clubs of Waimanalo, Oahu, and Lahaina and Haiku, Maui.

Fairs and demonstrations.—Three girls from the Pollyanna Club publicly demonstrated proper methods of canning fruits and vegetables during each of three days at the Territorial Fair in October (fig.9), and creditable exhibits were entered by the canning clubs of Haiku, Maui, and Honolulu, Oahu. The Territorial garden clubs were allowed a space 350 feet long and 90 feet wide on which to exhibit their work at the fair grounds. The area was divided into 34 plats, each 18 by 20 feet in extent. (Fig. 10.) Club members confined their efforts to growing one crop, such as the sweet potato, peanut,

eggplant, carrot, or taro, since single crops can be more readily marketed than small lots of miscellaneous vegetables. The club member producing the best crop was awarded a medal and a ribbon. Six schools, each entering four boys, participated in the school-garden contest held on part of the fair grounds, and members having the best gardens were awarded silver cups and ribbons. Demonstrations were given in spraying, proper methods of removing nut grass, using the hand cultivator, and preparing and applying fertilizers.

Segeichi Matsumoto, a member of the pig club of Laupahoehoe, Hawaii, was awarded an educational trip to the Territorial Fair for doing the best pig-club work in Hawaii, and the Maui Chamber of Commerce arranged to send five boys and girls from Maui to the fair, August 31 to September 9, 1925. The Haleakala and Haiku

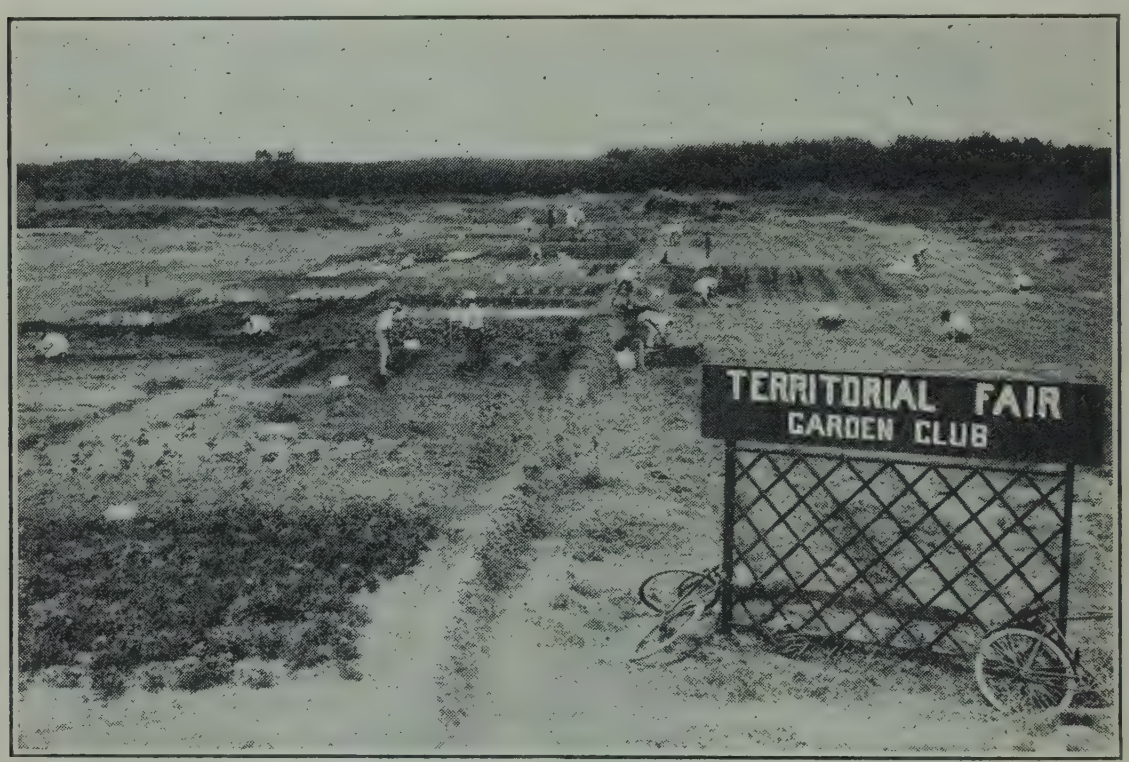

FIG. 10.—Boys' garden club plats at the Territorial Fair, Honolulu

pig clubs entered 15 exhibits at the Maui County Agricultural Fair in October. Cash prizes and four pigs, given by the Maui Swine Breeders' Association, were awarded winning members. The Haiku canning club demonstrated proper methods of canning at the fair.

Excellent exhibits were entered by the clubs in the Hawaii school fair, held at Hilo in May. Among them were purebred poultry and rabbits, and two young pigs which were raised from a litter by a club boy doing second-year work. Interesting and educational work was done in connection with swine, poultry, corn, rabbit, and potato judging contests, and winners of the best products were awarded cash prizes by the Agricultural Club of Hawaii, and ribbons and certificates by the fair association. The first 4–H club exhibit in Kauai was made in May by the Boys' Home Garden Club of Kapaa. This is a 100 per cent club, since every member reported.

HAWAII AGRICULTURAL EXPERIMENT STATION
HONOLULU, HAWAII

Under the supervision of the
UNITED STATES DEPARTMENT OF AGRICULTURE

Washington, D. C. April, 1927

REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION, 1926

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SUMMARY OF INVESTIGATIONS

By J. M. Westgate, *Director*

The station continued its established policy of fostering the development of diversified agriculture in the islands. Among the minor crops, pigeon peas and edible canna are giving most promising results in yield and ability to increase the agricultural output in sections that are not adapted to the production of sugar cane and pineapples, the two local major products. Pigeon peas are successfully grown on ranches and smaller farms and can probably be grown also to advantage on the marginal lands of plantations where sugar yields are almost too low to be profitable. The pigeon pea is expected to demonstrate its value as a forage crop on these marginal lands and also to improve soil fertility to such an extent as to make sugar-cane production there considerably more profitable than it now is. Edible canna has proved its ability to produce yields at altitudes that are not suited to sugar-cane cultivation and in localities that are too wet for pineapple production. Edible canna can be grown without competing with the two major crops as regards occupation of the land, and gives promise of adding a starch-producing industry to the islands with the development of suitable markets for the profitable outlet of the commercial product.

Work of the horticultural division was devoted largely to introducing new and improved varieties of economic plants, including citrus, breadfruit, grapes, avocados, dates, and Persian walnuts. Considerable work was done in an endeavor to develop more effective methods of budding and grafting. Approximately 40,000 small plants and packages of seed of improved varieties were distributed to local growers for trial. Variety tests are under way with the more promising

species of tropical and subtropical plants. The horticulturist served as chairman of the committee on fruit exhibits at the Territorial fair, which was held from August 31 to September 9, 1925, and as one of the judges of the Star-Bulletin school-garden contests.

Agronomic work was directed primarily toward the development and improvement of locally grown diversified crops. It was greatly hampered by the unusually dry weather, which seriously curtailed the available water supply for irrigation. Four major projects under investigation and experiment included (1) root crops for man, stock feed, and starch production; (2) ginger culture; (3) Mendelian studies with Guam corn hybrids; and (4) lettuce breeding to develop a hardy solid-headed strain for the lower altitudes. Experiments were made with vegetables of oriental origin to determine their cultural requirements and possible place in the dietary of the people of the various nationalities living in Hawaii. Numerous small lots of seed and vegetative planting material of various crops were furnished to interested growers. In addition to his regular duties, the agronomist continued to serve as secretary at the poultry show of the Territorial fair, and to assist local poultrymen in problems connected with the industry. In cooperation with the extension division of the University of Hawaii, he gave a series of lectures on poultry keeping on Kauai for the benefit of assembled groups of farmers. He also made a trip to Molokai during April to study the present status of cantaloupe and watermelon production on that island.

The solution of technical problems arising in connection with the edible canna industry is regarded as one of the major projects of the chemical division. Considerable time was devoted to the crop because the starch is thought to have potential possibilities for commercial use. The tri-local experiment with vegetables, grown from the same seed stock in Hawaii and in different places on the mainland, was completed. The results show no essential differences in the mineral constituents of Hawaiian as compared with mainland-grown vegetables. The making of jams, jellies, and glacés was continued to learn the best methods of preserving Hawaiian fruits, and methods were devised for testing fruit juices for jelly-making qualities.

The extension agent for the island of Hawaii again assisted farmers in solving problems in crop production and marketing, and in extending the culture of the edible canna, distributing locally grown pasture and forage crop seed, seedling trees for windbreaks, and literature dealing with agricultural topics, obtaining improved varieties of seed from the mainland, and establishing grass demonstration plats. He also assisted very materially with the boys' and girls' club work and Boy Scout activities, acted as chairman of the agricultural section of two school fairs, and as judge in the school-garden contests. During the year he traveled approximately 10,000 miles, mostly by automobile, visiting farmers in different parts of the island.

Boys' and girls' 4–H clubs were organized and conducted on the islands of Oahu, Maui, Hawaii, and Kauai. (Fig. 1.) The activities were carried on in cooperation with the Territorial department of public instruction and the International Institute of Honolulu. New 4–H sewing, gardening, and potato clubs were organized in Hamakuapoko, Maui; garden clubs in Lihue and Koloa, Kauai; cooking clubs in Hilo and Honokaa, Hawaii; and sewing and agricultural clubs in Pepeekeo, Ookala, and Pauilo, Hawaii. Club work was conducted

in the same communities as last year, but on a more extensive scale and with a larger membership than formerly. A total of 1,320 children enrolled, with 1,070 members, or 81 per cent, completing their projects. The club leader made three visits each to Maui and Hawaii, and one visit to Kauai during the year, and gave about 75 per cent of her time to field work, attending club meetings and making personal visits to club members, and devoted the rest of her time to office work at the station.

At the Haleakala demonstration farm, which is conducted to determine what kind of agricultural practices are best adapted to that part of the island in which the farm is located, approximately 149 varieties of 42 kinds of crops were tested, and numerous small lots of planting material were furnished to homesteaders and others for trial.

FIG. 1.—Club contestants and demonstrators. A, Canning team, Oahu; B, canning and cooking club, Honolulu; C, canning team, Maui; D, poultry-judging team, Lillian Baptist, Helen Donaghho, Harry Medeiros, and judge, J. O. Dale, of the University of Hawaii; and E, Kineuyo Mioken, sewing-club contestant, Maui

REPORT OF THE HORTICULTURAL DIVISION

By W. T. POPE

Cultural experiments were continued with certain crops which are commercially important or give promise of becoming so, but normal plant growth was maintained only with difficulty because of the drought that prevailed throughout the year and the general shortage of water for irrigation. The experiments are divided into two classes, the first including the more permanent, perennial crops like citrus, mango, avocado, banana, litchi, grape, and Macadamia nut, and the second, annual crops, such as tomato, poha, and roselle.

CITRUS FRUITS

The citrus orchard at the central station was begun some years ago and now contains many valuable varieties of citrus fruit trees, including oranges (14 varieties), lemons (5 varieties), limes (4 varieties), pomelo (11 varieties), mandarin (6 varieties), and 7 other miscellaneous citrus of different species. The orchard represents the largest collection of citrus varieties in the Territory, and is of value as a source of propagating material. The results of experiments in this orchard have shown the possibilities of producing certain kinds of citrus fruits in Hawaii. The orchard was thoroughly pruned and sprayed during the year. The continuous dry weather interfered with regular cultivation and prevented the growing of desirable cover crops to improve the soil and protect it against erosion in winter.

A number of introductions were received from Florida, California, and Australia, the most important varieties being the Cleopatra mandarin and the trifoliate orange, which are recommended for seedling rootstock material. Propagating material of several varieties of grapefruit was received by mail in excellent condition.

MANGOES

The old mango orchard contains trees of 18 varieties, most of which are known locally as (East) Indian varieties. The trees were too closely planted, and in order to give them more air and light some of the least desirable varieties were removed during the year and others were rather severely pruned. The orchard was sprayed with Bordeaux mixture for the prevention of mango blight (*Glœosporium mangiferæ*), which may prove to be a serious menace at blossom time if there is considerable rain. The fungus fortunately did not appear this year, except in very mild form on the young fruits of the Brindabani. At the station this variety is usually attacked by the fungus. (Fig. 2.)

The young mango orchard, which was started in November, 1923, contains 37 trees, representing 11 varieties. The trees were set alternately at 25-foot intervals in 3 rows 30 feet apart to form a windbreak on the northeast side of the citrus orchard, and have made good growth as the result of receiving good culture. The orchard is already of value for studying the habits of growth of new mango varieties, and should soon be of additional value for furnishing data on fruit production and resistance to adverse conditions, especially to attack from insect pests and fungus diseases. In an interplanting experiment, two rows of papayas 8 feet apart are being grown between rows of mangoes, with tomato plants 4 feet apart in the spaces remaining. (Fig. 3.) Several of the mango varieties produced fruit which matured in time for display in the horticultural exhibits at the Territorial fair.

During the early part of the fiscal year, 1,300 mango seeds were germinated, and the resulting seedlings grown in gallon tin containers to furnish rootstock material for grafting experiments in which form of union, age of material, and nature of growth were studied. Much of the surplus material was used in demonstrations and in trial plantings carried on in cooperation with experimenters in various parts of the Territory.

FIG. 2.—The Brindabani mango (accession No. 1372), a prolific Indian variety, but susceptible to attack by the fungus *Glœosporium mangiferæ*

FIG. 3.—Young mango orchard interplanted with papayas and partly with papayas and tomatoes

AVOCADOS

Cultural experiments with avocados are in progress at the Tantalus substation where conditions of altitude (1,000 feet) and rainfall are more suitable for the fruit than at the central station. The orchard contains nearly 100 trees representing numerous varieties of avocados. It is located in a clearing with the trees set in terraces along the contour lines of the mountain side. Many of the trees of the first planting of 1919 have already come into bearing. The later plantings have not yet begun to blossom. During the year many of the older trees blossomed heavily, but most of them failed to set fruit, probably because of the lack of sufficient moisture.

Young seedlings for propagating experiments are grown at the central station, and much of the stock is used in trying various forms of graft unions and in demonstration work. Several new varieties

FIG. 4.—Storey avocado (accession No. 5151), a West Indian variety grown by William Storey, Honolulu and now being propagated at the station. Fruit, oval-shaped, rich apple green, speckled; weight, 1 to 1½ pounds; rind, medium thick, rather tough; flesh, yellow, buttery, fiberless, nutty, and of pleasing flavor. Seed, loose in cavity and weighs 1½ to 2 ounces

were studied as to nature of fruit, and propagated by grafting methods. (Fig. 4.)

PAPAYAS

Twelve different trial plantings, varying in number of plants from 15 to 185, are fruiting at the station (June 30, 1926). Each planting is from the seed of fruit representing some particular type, form, or character, such as is found in the Solo, a new strain from Samoa, the so-called Dapitan from the Philippines, and the "Cowley" from Queensland. Seven of the sex forms found among these plants have been described.[1] With the long-fruited, monoecious kind, 15 plants

[1] Hawaii Sta. Bul. 32, The Papaya in Hawaii.

FIG. 5.—Part of a plat of 35 papaya plants varying in form of plant and in form of fruit. The plants on the right are from seed of the Dapitan (accession No. 5097), the original of which was introduced from the Philippines in 1922. The two plants on the left are a part of a separate plat

FIG. 6.—Papaya plants in fruit. First two plants from seed of a long-fruited variety (accession No. 5103). Planted July 27, 1925, and photographed May 14, 1926. Note the two distinct shapes of fruit produced by flowers also of different form on tree on right

of a single accession number have shown as many as four of the sex forms. Some of the plants exhibit marked variations in nature of growth and form of fruit, showing not only differences in shape of fruit of individual plants (figs. 5 and 6), but also differences in shape of fruit on the same plant. Differences in shape, and oftentimes in color of flesh and flavor are probably not due to cross-pollination but to mutative conditions, which are delayed in some instances until a definite growth of plant has been made.

The average home gardener often has difficulty in getting seed to germinate and has better success with transplanted seedlings. The station prevents a shortage of various economic plants by maintaining for distribution to all parts of the Territory a supply of improved seedling varieties. During the year numerous requests for the papaya plants were filled by the division.

BANANAS

Varietal tests with bananas have been conducted both at the central station in Honolulu and at the Tantalus substation. Determining the relative resistance of several varieties to dry weather conditions probably was the most important work with bananas during the year. The Brazilian and Lady Finger varieties produced fairly good bunches of fruit, whereas other varieties bore fruit of unusually poor quality. Many of the plantings show signs of deteriorating, due to the length of time they have occupied the same clumps. Interest in banana culture is being renewed, and demands for the planting material are increasing.

During the year a bulletin on banana culture was submitted for publication.[2]

LITCHI

The litchi trees in the station orchard blossomed lightly and rather irregularly during the year. They produced normal foliage, but failed to set fruit. This condition prevailed rather generally with litchi trees in the Territory. Litchi trees require a very special culture in which fertilizers and water in abundance form an active part. About 150 seedlings were grown in gallon containers for use in budding experiments and in cooperative work with interested growers.

MACADAMIA NUT

Macadamia nut culture is assuming the proportions of an industry, which is as yet, however, in the experimental stage. Interest in the crop increased considerably during the year, and numerous requests were received for seeds and seedling trees. Areas devoted to the crop were extended on Oahu and in Kona, Hawaii. Several old trees at the Tantalus substation produced a light crop, the seed of which was utilized for propagation purposes. Resulting seedlings were used in cooperative experiments and for grafting experiments at the central station.

Fifty Macadamia trees which were planted at the Tantalus substation in December, 1921, are now 15 to 20 feet high. Approximately 50 trees, which were started in 1918 in cooperation with T. C. White at Kealakekua, Kona, Hawaii, came into bearing, and many of them

[2] Hawaii Sta. Bul. 55, Banana Culture in Hawaii.

are unusually tall. Experiments are under way to determine the effect of pruning on Macadamia trees under Kona conditions.

FIGS

Four varieties of figs are growing in the station orchard. The trees have been greatly reduced in vigor by the removal of cuttings for distribution to growers throughout the Territory. The propagating material is very much in demand for growing in home gardens. In Hawaii the fig is used as fresh fruit.

GRAPES

The vineyard, consisting of about 200 plants, was set out early in 1921. A number of vines of the Isabella grape, the original variety grown, have been grafted over to other varieties. Of 12 varieties now growing successfully, 6 have already fruited. During the year the vineyard was cultivated, pruned, fertilized, and sprayed. Several thousand cuttings were rooted for growing in cooperative experimental plantings. The cuttings can be rooted easily if they are placed in propagating beds of coral sand in the open sunlight. No difficulty was had in shipping the plants, either by mail or by freight, when the roots were properly packed in moist sphagnum moss.

TOMATOES AND ROSELLE

Considerable work was done with tomatoes and the roselle. Fourteen selections of tomatoes from crosses made two and three years ago have been grown in the hope of establishing hybrids with well-fixed characters. Seeds of a number of varieties from other countries have been tested and some of them indicate adaptability to Hawaiian conditions.

The roselle as a jelly fruit continues to be popular in Hawaii. The plant is an annual and is propagated from seeds. Owing to the difficulty of properly storing the seeds, many gardeners find themselves in need of a new supply when planting time arrives. Several thousand roselle plants were distributed by the station during the year.

PROPAGATION EXPERIMENTS

New plants at the station are propagated from seeds and by vegetative methods. Seedlings have been produced from the mango, papaya, citrus, grape, avocado, pomegranate, dates, Macadamia nut, guava, sapota, sea grape, pepper, carambola, star apple, and Annona species. Vegetative propagation methods have been successfully employed with the avocado, mango, citrus, breadfruit, fig, banana, mulberry, and litchi.

MISCELLANEOUS INTRODUCTIONS

Among the introductions of the year were grapes (several varieties), citrus (8 varieties), jujube, jaboticaba, avocados (3 varieties), dates (3 varieties), one of which received the first award at the Hawaii Annual Territorial Fair, 1925 (fig. 7), hickory nuts, papaw (*Asimina triloba*), Persian walnuts, cashew nuts, sunberry, Samoan and red-fleshed papayas, Queensland raspberry, seed of the new Burpee tomato, and root cuttings of a number of varieties of breadfruit from the Society Islands.

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HORTICULTURAL EXTENSION WORK

Demonstrations were carried on in the propagating house and in the field for the benefit of students of the public schools, the Kamehameha schools, and the horticultural classes of the University of Hawaii. Demonstrational work was conducted also to assist private growers both at the station and in various home gardens. Seven large experiments were continued in cooperation with private growers.

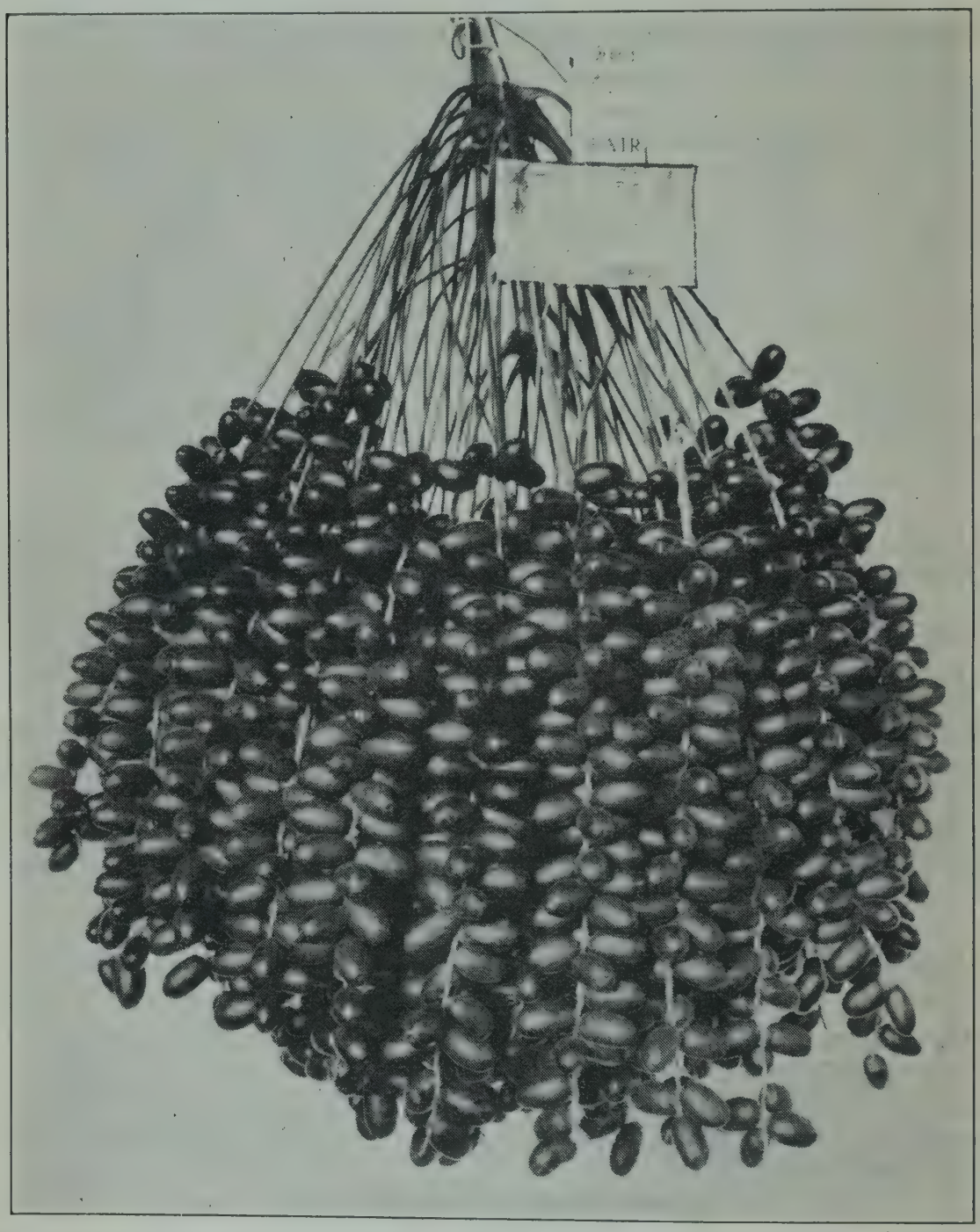

FIG. 7—Dates from a seedling of the Deglet Noor variety, grown by Miss Steritt, Girls' Industrial School, Honolulu, and awarded the first prize at the Fourth Hawaii Territorial Fair. Weight, 56¾ pounds

The horticultural division was again the recipient of numerous requests for advice and information, and distributed bulletins and other printed matter of interest to local growers. The horticulturist acted as one of five judges who inspected 20 public-school gardens four times each on Oahu, and made side trips twice each to 16 individual home gardens which were under the care of school children

He also served as chairman of the committee on fruit exhibits at the Hawaii Annual Territorial Fair, and made a number of official trips to Oahu and Hawaii to assist in cooperative experimental work.

REPORT OF THE AGRONOMY DIVISION

By H. L. Chung

WHITE POTATOES

Three varieties of white potato, the Burbank, the Hamakua strain, and an unidentified sort resembling the Netted Gem, have been studied during the last two years to learn the relation of earliness to productivity. All three varieties yielded uniformly well notwithstanding the unfavorable weather prevailing at the time the crop was growing.

A small planting of the purple-skinned variety known locally as the "Portuguese Purple" was made for the purpose of restocking the seed supply. The variety bloomed profusely and seeded. So far

Fig. 8.—Sweet-potato breeding plat

as it is known, this is the first time any variety of potato has formed seed balls at the station (50 feet above sea level). The three varieties first mentioned also bloomed heavily, but formed no seed balls.

Two hundred pounds of choice station-grown potatoes were distributed for planting to growers of Palolo and Kailua, Oahu. The farmers of these places are cooperating with the station in establishing a fertilizer experiment with potatoes.

SWEET POTATOES

Several varieties of promising sweet-potato seedlings bloomed simultaneously with a number of standard varieties. (Fig. 8.) Reciprocal crosses were made and produced a total of 321 seeds. The flower-bearing varieties bloomed profusely. Blooming usually ceases about April, but a large number of the plants continue to flower until the middle of May. Seedling No. 1804.1 is still producing flowers (June 30, 1926), which is rather late for the sweet potato in Hawaii.

TARO

The Samoan variety of taro, or kalo (*Colocasia* sp.) which was received by the station last year, was harvested June 7 after a growing period of 13 months. Poi was manufactured from the crop at one of the local factories, and the quality compared with that of poi from locally grown taro. The Samoan variety is considered decidedly superior to the Hawiian taro in consistency, but those who assisted in the palatability tests were divided in opinion so far as the taste is concerned.

Fifteen hundred taro plants of the Samoan variety were distributed to large and small growers throughout the Territory. It is hoped that more propagating material may be obtained for further planting. The taro cultural experiments were hampered by the drought, and the collection of varieties was transferred to the upper Tantalus substation in the hope that moisture conditions there would prove to be favorable to the crop. No distinct advantage was gained by the transfer, however, because of the general drought which lasted until about June 15.

EDIBLE CANNA

Because of the increasing value of edible canna as a starch-producing plant and feed for livestock, cultural tests with the crop have been extended, especially at Waimea, Hawaii, under the immediate supervision of the chemical division. In the agronomy division crossbreeding was continued for the production of one or more promising seedling varieties or strains proving equal or superior in yield and quality to the commercial variety. These supplemental varieties will be held in reserve for use in case the ordinary variety is attacked by disease or insect pest, or deteriorates.

GINGER

Unfavorable weather conditions and poor planting material retarded progress of the ginger projects. The plants showed signs of renewed growth with the occurrence of periodical light rains and cool mornings toward the close of the fiscal year. The project is to be repeated on a larger scale and in cooperation with a corporation at Kailua, Oahu.

Ginger is an important minor crop in Hawaii at present. Interest in the condiment has probably been stimulated by brisk demand from the mainland for the fresh roots for use presumably in manufacturing ginger ale.

LETTUCE BREEDING

Seeds of a number of varieties of head lettuce were collected and planted to determine those which are best adapted to the warm lowlands of the island of Oahu. (Fig. 9.) The varieties Los Angeles "Best," Los Angeles "White," Iceberg, Immensity, Hanson, All-Seasons, May King, and California Cream Butter were grown in the first trial planting, and individual plants of the six varieties first mentioned were selected for hybridizing. Toward the close of the year a total of 233 crosses had been made and numerous seeds obtained.

FIG. 9.—Lettuce-breeding plat

FIG. 10.—*Exophorus unisetus*, a promising pasture grass for Hawaii

CORN

During the last two seasons crosses have been made with Guam corn and several varieties of sweet corn in the hope of developing a sweet variety combining stockiness with the ability to resist the corn leaf hopper (*Peregrinus maidus*) attack characteristic of the Guam variety. The best ears from the most prolific and stocky resulting plants were selected for further breeding work.

FORAGE GRASSES

A fertilizer experiment was conducted with *Exophorus unisetus* (fig. 10), a promising grass for Hawaii, especially as a feed for dairy cattle and for poultry. Poultry and cow manure were included in the experiment to compare their relative efficiencies as fertilizers with the commercial kinds. Notwithstanding the dry weather prevailing, the demonstration grass areas were successfully maintained for the production of seeds and cuttings for distribution to ranchmen and to others who are interested in grasses.

MISCELLANEOUS CROPS

Several varieties of radish (*Raphanus sativus*) and 10 strains of Chinese cabbage (*Brassica pekinensis*) have been under test at the station. Cabbage yielded at the rate of 5 to 30 tons per acre, and the large radish varieties at the rate of 11 to 35 tons per acre.

Plantings to replenish the seed supply for the planting season of 1927 were made of beans (*Phaseolus vulgaris*, 5 varieties), peanuts (*Arachis hypogea*, 3 varieties), Chinese spinach (*Amaranthus gangeticus*, 3 varieties), Jerusalem artichokes (*Helianthus tuberosus*), and sorghum (*Andropogon sorghum*).

THE CHAYOTE AS A POSSIBLE TRAP FOR MELON FLIES

A study was made of the chayote as a possible trap crop for the melon fly (*Bactrocera cucurbitæ*). Watermelon and cantaloupe growing is gaining in commercial importance, especially on Molokai, but successful culture of the crops is seriously retarded by the melon fly. Observations showed that the flies oviposit in large quantities on chayote fruits, but no live maggots were to be found on the same fruits when examined several days later. Further observations are necessary to determine definitely whether the chayote can be used in melon fields to help reduce infestation by the melon fly.

DISTRIBUTION OF SEEDS AND CUTTINGS

Heavy demands were made upon the agronomy division for seeds and cuttings. A comparatively large part of the distribution was made to contestants in the school and home garden work and to homesteaders on Molokai.

Distribution of seeds and cuttings from July 1, 1925, to June 30, 1926, was made in quantities as follows:

Seeds and cuttings distributed during the fiscal year ended June 30, 1926

Crop	Seed	Cuttings	Crop	Seed	Cuttings
	Pounds	*Number*		*Pounds*	*Number*
Alfalfa	18		Chinese spinach	3	
Beans	195		Potatoes	200	
Cowpeas	37		Edible canna tubers	3,000	
Corn	229		Cassava		96
Grass	7		Napier grass		1,700
Pigeon peas	35		*Exophorus unisetus*		5,086
Peanuts	110		Sweet potatoes		13,000
Lettuce	7		Taro		1,500

REPORT OF THE CHEMICAL DIVISION

By J. C. Ripperton

EDIBLE CANNA INVESTIGATIONS

FIELD WORK

Experimental work with edible canna was continued on a field scale at the central station in Honolulu (figs. 11 and 12) and at Waimea, Hawaii. One crop was harvested during the year in an effort to learn the effect of varying the quantities of irrigation water on yield and manner of growth of crop and on the physical properties of canna starch. In another experiment, undertaken to learn the progressive growth of individual hills from the time of germination, each stalk is being tagged as it appears. Results so far indicate a decided cyclic rather than a continuous growth of hill. The experiments are to be duplicated at Waimea to learn if the cyclic growth is made there and what environmental factors cause it. The data may have a practical bearing on various factors including time of planting and of harvesting.

Fig. 11.—A single hill of edible canna, 5 months old. Grown at the central station, Honolulu

Experiments were begun to improve the species through individual selection. Whether the species is sufficiently pure to preclude mass selection is not known, but the possibility is suggested by the very great differences in the size of adjacent hills from apparently similar seed. The work will be hastened by harvesting and by repeating the experiment at 6-month intervals, instead of 12 to 18 month periods.

Plantings of edible canna rootstocks from Queensland were harvested and the resulting seed was used in extending the area devoted to the crop.

Edible canna experiments, begun at Waimea, Hawaii, in July, 1923, in cooperation with the extension agent on Hawaii, are yielding conclusions of immediate value in altering present field practices with the crop. The experiments deal with tuber selection for planting, number of tubers per hill, the effect of spacing and depth on yield of tubers, the feasibility of mulching with canna tops, and the best time of harvesting and applying fertilizers. The crop was harvested during the year at 20 months from planting and yielded an average of about 35 tons of rootstocks per acre. This is nearly double the yield obtained at the central station, and points to the remarkable adaptation of the crop to the rather unusual soil and climate at Waimea.

FIG. 12.—Base of a hill of edible canna, 5 months old

In another experiment, occupying a 4.7-acre plat, several types of seed material giving the most promise in the above-mentioned experiment, were planted to determine the effect of continuous use on each. Seed was selected from corresponding plats in the first experiment and also from exceptionally large hills, vigorous lines, and from rootstocks of exceptional size and of high starch content. Studies are being made comparing the effect of age on "seed" and of storing the "seed" for varying lengths of time, and of the relative economy of planting single, selected "seed" with double unselected "seed." In addition, a 1-acre plat each is devoted to single "seed" and double "seed" plantings to determine the rate of growth of the crop by means of monthly harvests of one-tenth-acre plats.

A red variety of canna, which was found growing in an experimental field in 1924, was carefully studied because of its exceptional

vigor, heavy yields, and desirable habits of growth as compared with the common variety. (Figs. 13 and 14.) A number of hills of the red variety when sufficiently mature were harvested for determination of the starch content of the rootstocks. Starch was also extracted from a number of the rootstocks, its morphology was determined, and the viscosity compared with that of the starch of the common variety. The properties of the starches of the two varieties were found to be similar, but the percentages of actual starch in the red variety proved to be too low to make it desirable for starch making. Seed and rootstocks of the red variety were submitted to the agronomist of the station for use in crossbreeding.

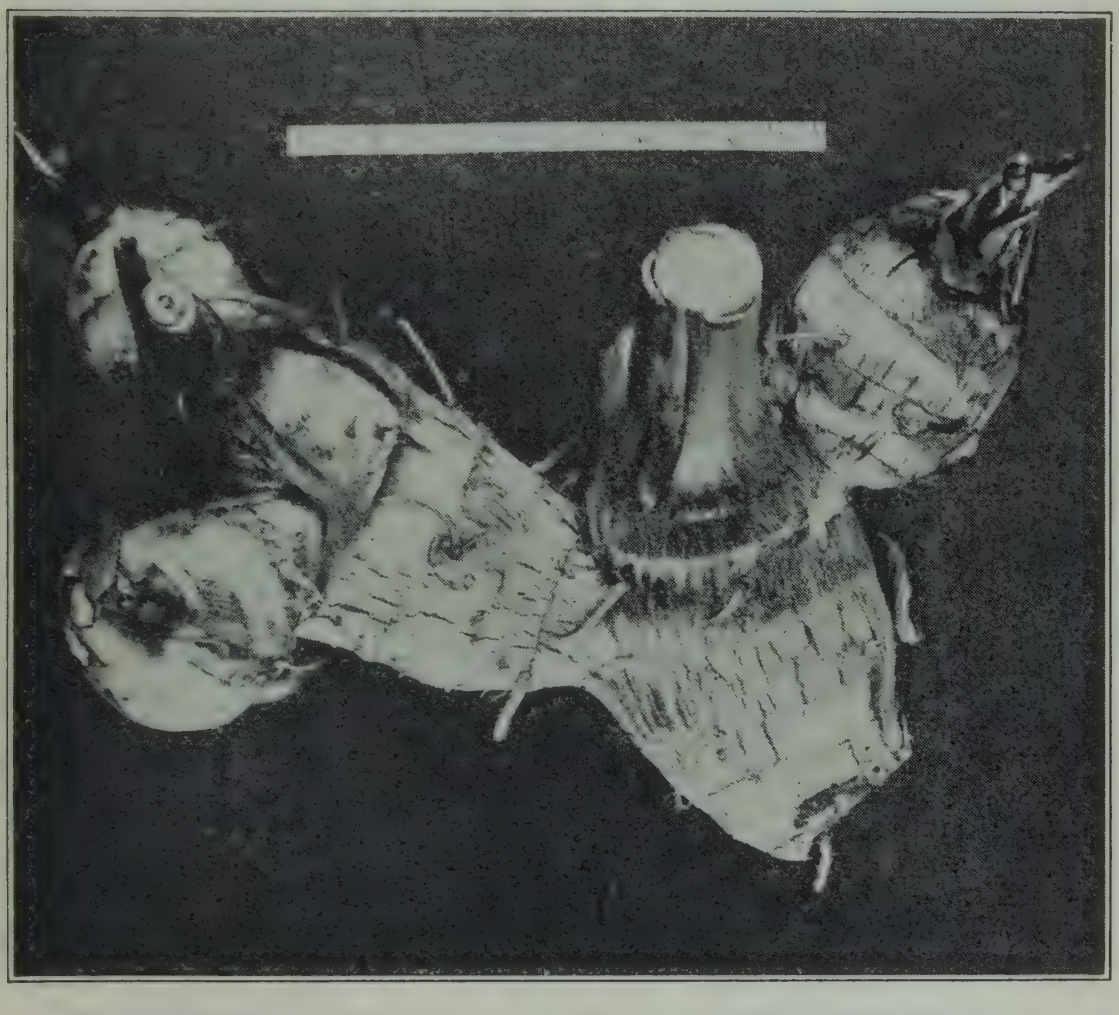

FIG. 13.—Edible canna rootstocks grown at Waimea, Hawaii. Weight, 3½ pounds

CARBOHYDRATE METABOLISM OF THE CANNA PLANT

Investigations begun during the fiscal year 1925 on the carbohydrate metabolism of the canna plant were completed and the results submitted for publication.[3] Sucrose was found invariably to predominate in the leaves of the plant. In proceeding down the stem, the sucrose decreases, whereas the hexoses rapidly increase, usually exceeding the sucrose. In the rootstock, sucrose again exceeds the hexoses, which decrease rapidly. The hexoses are therefore thought to be primarily concerned with translocation, and sucrose to be related to the photosynthetic process, and existing as an intermediate product

[3] Hawaii Sta. Bul. 56, Carbohydrate Metabolism and Its Relation to Growth in the Edible Canna.

between the hexoses and the starch, the final product. With relation to growth, the hexoses of the stem and the sucrose of the rootstock seem to correlate rather closely with the rate of storage of starch in the rootstock. Formation of starch continues normally in the rootstock until it becomes quite old, and the rate of translocation of sugars, as measured by the concentration of the hexoses, is at the maximum in the mature stems. A table has been constructed making it possible to determine in the factory the approximate percentage of starch in a rootstock from its specific gravity.

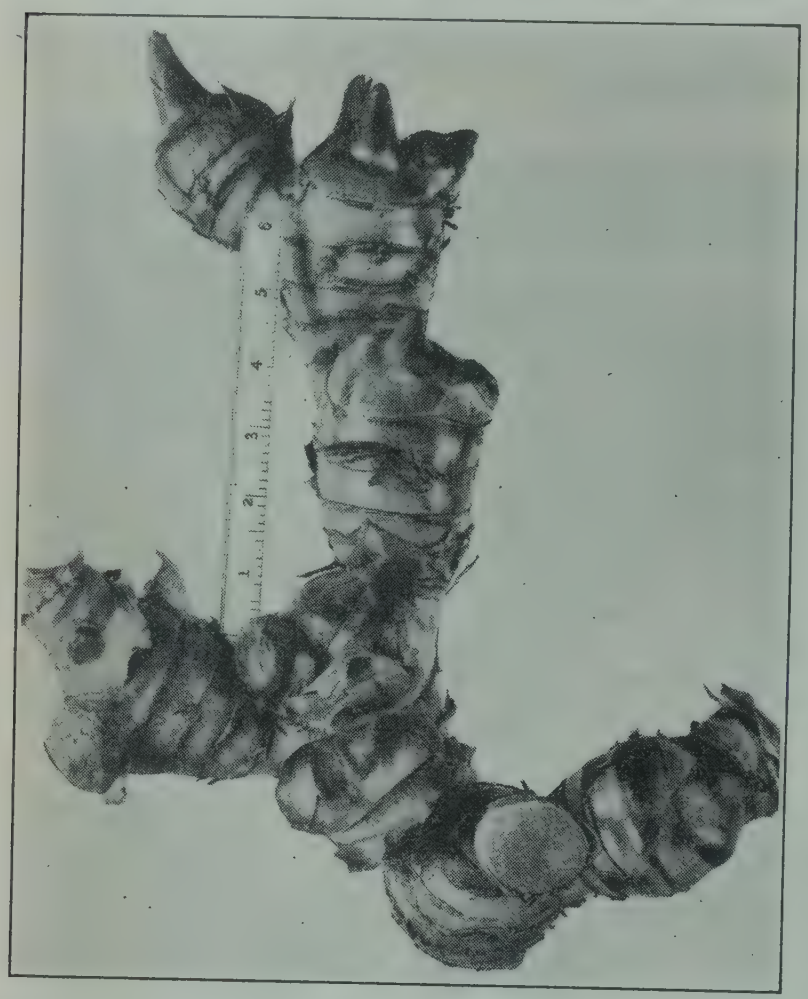

FIG. 14.—Rhizomes of a red variety of canna found growing in Waimea, Hawaii

MILL CONTROL METHODS

Two methods were developed for the control of the milling process in the starch factory. The first is an adaptation of the procedure used to determine the percentage of moisture in potato starch, and serves as a control of the moisture content of the starch in the drying tunnel. The second makes possible the determination of the viscosity of the finished product. An inexpensive pipette viscosimeter was devised for the purpose. This instrument is easy to operate and capable of giving results that can be duplicated as closely as when a more expensive one is used.

EFFECT OF VARIOUS FACTORS ON THE PROPERTIES OF STARCH

Samples of canna starch which were collected from miscellaneous sources were found to vary greatly in viscosity. In the hope of producing a canna starch of uniform quality, work was begun to determine the effect on the starch of various factors including climate, age of crop, milling process, storage of rootstocks, wetting, and drying at different temperatures and humidities. Laboratory results are tried out in a local starch factory, which submits to the station for analysis the samples of starch obtained by the different procedures. (Fig. 15.)

MINERAL CONSTITUENTS OF EDIBLE CANNA

The excessive growth of the stems and rootstocks of the canna plant at Waimea must of necessity effect a heavy drain upon the soil. No appreciable response of the plant to fertilizer has been made thus far,

although the soils of the district have never been heavily cropped. A falling off in yield is certain to occur soon unless fertilizing material is systematically applied to the soil to maintain fertility. Samples of the stem and rootstock of various ages have been collected for determination of their chief mineral constituents, and samples of the pulp are being analyzed for determination of its fertilizer value.

POSSIBILITIES OF THE PULP AS A FEED

The apparent palatability of the waste pulp from the starch factory suggests the possibility of using the material as a carbohydrate feed either in the fresh state locally or in the dried state for export to the

FIG. 15.—Refining and drying room of edible canna starch factory

Pacific coast. Samples of the pulp are being analyzed to learn how it compares in feeding value with similar carbohydrate feeds on the market.

PRESERVATION OF HAWAIIAN FRUITS

Fruit growers, especially on the island of Hawaii, continue to show interest in the development of an export trade furnishing miscellaneous tropical fruit products to markets of the mainland. The island of Hawaii is capable of producing a wide variety of cultivated fruits. It has large areas of waste land on which the guava grows in abundance. Fruit production on Hawaii is greatly limited, however, by the difficulties entailed in shipping the fresh fruit to Honolulu, Oahu. The chemical division is rendering assistance to fruit-preserving concerns by submitting for their use plans for up-to-date preserving machinery and data and recipes regarding locally grown fruits, and by developing methods for testing juices for jelly-making qualities and for determining the physical properties of the jelly.

COMPOSITION OF HAWAIIAN-GROWN VEGETABLES

Analyses were completed of a series of 60 different vegetables, chiefly of oriental origin. Determinations were made of their nutritive constituents, and of calcium, phosphorus, iron, total ash, and alkalinity of ash, and the results are being prepared for publication in cooperation with the agronomy division. The results strikingly show that Hawaii can and does produce a large variety of vegetables which are rich in all the necessary food and mineral constituents.

In connection with the tri-local vegetable experiment, analyses are being made of the second season's crop of vegetables grown on the mainland (Virginia and Oregon) and in Hawaii (Mokuleia, windward Oahu, and Honolulu).

HALEAKALA SUBSTATION AND DEMONSTRATION FARM

By H. F. Willey

At the Haleakala substation and demonstration farm 2½ acres of gulch land was cleared and made available for pasture. Wires were strung on 40 rods of new fence. Two hog houses, one brooder house, and four small poultry houses were built, and 250 feet of pipe was laid to furnish water for the poultry and the livestock. A registered Holstein bull (fig. 16) and a purebred Duroc-Jersey boar are kept for community service. Approximately 149 varieties of 42 crops are under test, including pineapples, pigeon peas, oats (fig. 17), field corn, sweet corn, pop corn, broomcorn, tomatoes, strawberries, squash, beans, sweet potatoes, edible canna, dry-land taro, cassava (fig. 18), forage grasses, and fruit trees. Distributions were made of approximately 26,000 cuttings of sweet potatoes and coarse grasses, 500 rootstocks of edible canna, 700 strawberry plants, and numerous small lots of seed of pigeon peas, beans, corn, tomatoes, and taro. Trees that were planted during the last four years on the windward side of the farm are now of sufficient size to form efficient windbreaks (fig. 19), and serve to demonstrate the possibilities of such plantings on wind-swept grasslands. Plantings for windbreaks, especially of *Eucalyptus robusta*, are being increased.

Fig. 16.—Holstein bull, Haleakala demonstration farm

The superintendent assisted in the pig and garden club activities, served as one of the judges of the garden contests, and also of the

exhibits at both the Maui County Agricultural Fair at Kahului and the Territorial fair at Honolulu, and acted as agricultural representative for the Maui County Chamber of Commerce. He also assisted

FIG. 17.—Sheaves of Red Texas oats harvested May, 1926, Haleakala demonstration farm

numerous farmers in solving farm problems, including obtaining and growing suitable varieties of crops, outlining methods of planting and

FIG. 18.—Roots of cassava planted June, 1925, and harvested June, 1926, Haleakala demonstration farm

harvesting, and marketing farm products. He aided the representative of the Smith-Hughes Vocational Education Act by demonstrating locally adapted methods of handling crops and livestock.

REPORT OF EXTENSION AND DEMONSTRATION WORK ON THE ISLAND OF HAWAII

By R. A. Goff

EXTENSION OF CULTURE OF THE EDIBLE CANNA

Some progress was made in the development of the edible-canna industry in the Waimea district. The area in the crop was extended, and a starch-extracting mill and refining plant were erected. A large number of the homesteaders on Hawaii should benefit from the establishment of the industry, because the crop thrives at high altitudes and can be grown in places which have been prevented by strong winds from being utilized for anything but grazing. In a number of experimental plantings made at Waimea in cooperation with the chemical division of the station, part of the edible-canna crop is being harvested monthly to determine increase in yield from the use of various fertilizers, optimum time of harvesting, and depth and distance of planting. Crops are being grown also for seed selection. Plantings of small plats of edible canna have been made at various elevations and in different districts to learn the adaptability of the crop to various climatic and soil conditions.

Fig. 19.—Windbreak trees planted October, 1922, and photographed May, 1926, Haleakala demonstration farm

BOYS' AND GIRLS' CLUBS

Boys' and girls' club work, including livestock-production clubs, field-crop production clubs, and domestic science clubs, was organized in the fall of 1925 in schools on the east side of the island of Hawaii. Meetings were held at the schools, club projects were inspected at the homes of members, and instructive demonstrations were given by the local club leader for the benefit of the club members. The advice and instructions given were recorded for future use. Boys who have belonged to some particular club for two years are being encouraged to join other kinds of clubs to gain a general knowledge of the different branches of livestock and crop production fostered by the various clubs. Many of the club members who through force of circumstances will have to leave school before finishing may devote their future energies to cane growing with pig and chicken raising as a side line. Club work affords splendid opportunities for school children to learn how to avoid making the costly

mistakes invariably made by beginners. This is true especially in poultry raising. Boys leaving school in the Territory have been erroneously led to believe that they can not acquire farming land even when they have earned and saved sufficient money to make the purchase. When land is available it can be purchased by any boy on the island of Hawaii having the requisite sum to pay for it. Club work is developing interest in agriculture among the boys and shows them the possibilities they have of earning a living in their own districts instead of having to work in town at some poorly paid job or work with gang labor for some large company.

SCHOOL FAIRS

Club members entered livestock and corn exhibits at the fair held by the Honokaa Junior High School. The extension agent acted as one of the judges of the school fair and assisted club members in bringing the exhibits to and from the fair. At another school fair, held in connection with the American Legion Industrial Fair at Hilo from May 20 to May 22, inclusive, livestock exhibits, including chickens, pigs, rabbits, pigeons, and calves, were entered by members of the boys' clubs and sewing exhibits by members of the girls' clubs. The extension agent acted as chairman of the agricultural section and had charge of the transportation, housing, and care of the animals on exhibition.

SCHOOL AND HOME GARDEN WORK

The extension agent frequently visited and finally acted as judge in the home garden work undertaken by club members in connection with the Territorial school garden contest. In the earlier visits he gave advice to the young gardeners concerning seed, fertilizers, record keeping, methods of combating garden pests, and marketing; and he also assisted the children in obtaining improved varieties of seed. In the later visits he gave advice on seed selection and summer planting.

GRASS DEMONSTRATION WORK

Plats demonstrating five or six varieties of forage crops and range grasses proving best adapted to local conditions were maintained or started at some of the schools. Farmers living near the schools were taken to the demonstration plats, helped to select the crops found to be best suited to their particular needs, and given seed with which to start the crops.

ASSISTANCE IN POULTRY RAISING

The extension agent visited various poultry farms and the homes of individuals raising small flocks for home use or as a side line to some other branch of farming, gave advice on feeding for increased egg production and regarding sanitation, and distributed plans for poultry-house construction. He also showed poultry raisers how to cure certain poultry diseases. Successful poultry raising is extremely difficult on the island of Hawaii because a large percentage of the birds is carried off by disease during rainy periods.

ASSISTANCE IN ORDERING SEED

Catalogues of reliable seed houses were loaned to homesteaders and ranchmen, advice and assistance in ordering good varieties of seed was given farmers, and seed and cuttings of pasture grasses

and perennial forage crops were distributed from the Kamuela cooperative experiment station, which is operated by the Parker ranch, to farmers living in all parts of the island.

DISTRIBUTION OF LITERATURE

United States Department of Agriculture Farmers' Bulletins and circulars were distributed to farmers from the office and by the extension agent on his trips over the island. Newspapers and magazines containing interesting articles on poultry, pigs, dairy cattle, and gardening were loaned to various farmers.

ASSISTANCE IN MARKETING

Demonstrations were given producers in methods of grading and packing farm products for shipment to the Hilo and Honolulu markets. Wholesale houses have standing orders with coast firms for a part of the produce consumed locally, but usually are willing to cancel these orders when well-timed arrangements can be made with local growers. The products are marketed with difficulty when the arrangements are made too late to be of avail. Cold-storage facilities were arranged for perishable products failing to find a ready market.

PLANTING WINDBREAKS

Over 4,000 trees were taken from the Territorial nursery at Hilo for distribution to farmers living in the Kolaha and Waimea districts, where strong winds blow during a large part of the year. These districts are 20 miles or more from the railroad and the residents have difficulty in procuring trees for windbreaks.

ASSISTANCE IN BOY SCOUT ACTIVITIES

The extension agent again acted as examiner for members desiring to qualify for agricultural merit badges and as scout commissioner for the island of Hawaii. Bulletins dealing with agricultural topics were distributed to Boy Scout troops at the posts for use in their libraries. Over 50 badges were distributed to those competing for agricultural merit badges.

TRAVELING

The extension agent traveled approximately 10,000 miles visiting farms, schools, truck gardens, ranches, and plantations on the island of Hawaii. He visited when possible every farm in each section one or more times during the year. In June, 1926, he made a trip to the central station in Honolulu for the purpose of establishing contacts with the station workers and of familiarizing himself with the latest developments along agricultural lines.

BOYS' AND GIRLS' CLUB WORK

By Mabel Greene

STANDARD CLUBS

The boys' and girls' 4–H standard clubs of the islands are distributed as follows:

Enrollment of boys' and girls' clubs, June 30, 1926

Club	Distribution				Total
	Hawaii	Kauai	Maui	Oahu	
Canning	0	0	25	15	40
Cane (sugar)	25	0	0	0	25
Clothing	336	0	84	432	852
Cooking	58	0	0	31	89
Garden	53	33	26	75	187
Pig	23	0	15	0	38
Potato	0	0	4	25	29
Poultry	16	0	0	24	40
Rabbit	21	1	0	0	22

FAIRS AND DEMONSTRATIONS

Members of the boys' and girls' clubs have entered exhibits in activities carried on in cooperation with school fairs and the Parent-

FIG. 20.—4-H clubs' exhibit, Educational Building, Hawaii Territorial Fair, Honolulu, August 31, to September 9, 1925

Teachers' Association. A demonstration in "good buymanship," a study of textiles, was given by two clothing club girls at one of the meetings of the Parent-Teachers' Association in the Kauluwela School, Honolulu. The demonstration was given in English and then in Chinese and Japanese for the benefit of the group of oriental mothers attending. Local fairs were held at Honokaa, Laupahoehoe, Hawaii. Seven boys from the Honokaa pig club exhibited pigs which they raised, and recorded the gains made per pig and the cost per pound of gain. Both the girls' and the boys' club work was judged.

At the last Territorial fair space was allotted club exhibits in one of the educational buildings (fig. 20), and members participated in contests during each of the nine days of the fair. After the fair the

Pollyanna Club sent canned locally grown fruit to Chicago for exhibition at the canning exhibit of the National Boys' and Girls' Club Congress, held from November 30 to December 5, 1925. The fruit exhibit was much appreciated and three members of the club were awarded 3 dozen glass jars by a glass-jar company entering its jars for contest at the congress. The jars are being filled for the coming fair by the club girls, and as an award did much to stimulate interest among the girls in food preservation. The Pollyanna Club held five sales of jellies, jams, and marmalades from Hawaiian fruits. The club leader attended the Fourth National Boys' and Girls' Club Congress at Chicago where many exhibits were entered for contest, 1,200 members of 4–H clubs were assembled, and a large number of club leaders from 42 States were present.

Excellent agricultural clubs were organized during the year on Kauai. These are ready for 4–H club work next year. The boys of the Hanamaulu School have done garden work for two years. The girls are eager for a home economics club or for any other kind of club which in the opinion of the school principal will benefit the community. Garden work is very successful on Kauai, which is known as the "Garden Isle," and ample land is available for gardening. The club leader frequently inspected the children's gardens, which often occupied the better part of the home garden plat. The parents were interested in the work being done and appreciative of the club leader's efforts to develop the spirit of gardening in the children, and the teachers reported increased interest in each school where a club has been located. The gardens themselves are better than ever before.

CLUB RECREATIONAL ACTIVITIES

Agricultural lantern slides were shown at meetings of two club groups, and achievement pins were awarded when possible at public school assemblies for finished club work as reported in the club record books. Some of the club records are better kept and more complete than were those of last year. The food habit score card has been kept in the record book of many members of the cooking clubs, preparatory to carrying on health work next year. Some of the girls are excellent bread makers, and report purchasing such home equipment as ovens, stoves, measuring cups, and spoons. Bread is now made in homes where formerly rice was served as the chief cereal food. The boys as well as the girls are doing canning work in Haiku, Maui. One of the boys, who has done club work for two years, is planning to raise poultry for market to defray his expenses through high school. Four 4–H home economics clubs were organized by a teacher in the International Institute of the Young Women's Christian Association. The girls are doing more satisfactory work than some of the mothers, many of whom are handicapped by foreign customs and a lack of knowledge of English.

Room improvement club work was started in Honolulu for senior high school girls wishing to improve their homes during the summer vacation period. The girls are making curtains, rugs, dresser covers, and box furniture, and in some instances are refinishing old furniture.

Several commercial companies are cooperating in club activities by furnishing merchandise prizes as awards to successful competitors in club contests and fair exhibit work.

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HAWAII AGRICULTURAL EXPERIMENT STATION
HONOLULU, HAWAII

Under the supervision of the
UNITED STATES DEPARTMENT OF AGRICULTURE

Washington, D. C. June, 1928

REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION, 1927

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SUMMARY OF INVESTIGATIONS

By J. M. Westgate, *Director*

During the year the station continued to encourage in every practicable way the development of a number of local minor agricultural and horticultural industries. Hawaii has been too long dependent upon the success of one or two crops. It is realized also that at least one additional agricultural industry should be developed to supplement the sugar-cane and pineapple crops, the leading products, in the event of calamity befalling them. The development of a more complete diversified agricultural program would make possible the utilization of lands which are not adapted to the leading crops. Moreover, it would furnish a variety of activities which would enable persons not wishing to engage in the present major industries to find employment better suited to their liking. Such diversity in the agricultural industries would naturally tend to offset the dangers resulting from labor unrest.

The station is especially interested in fostering the development of the edible-canna industry. The crop is comparatively new in Hawaii, gives promise of adding a starch-producing industry to the islands, and can be grown on thousands of acres of land that are not suited to pineapple and sugar-cane cultivation. Plans have been formulated and experiments started to determine to what extent edible canna can be utilized by the leading agricultural industries, turning the tops under as a green manure and using the rootstocks as a source of commercial starch or as a stock feed. A market has recently been developed for the starch at a price only slightly lower than that prevailing for sugar.

The pigeon pea (*Cajanus indicus*) continues to demonstrate its value as a forage crop, and efforts are being made to develop strains that will mature at the higher elevations throughout the islands. Arrangements have been made with F. G. Krauss, collaborator of the station and agronomist at the University of Hawaii, to visit the Himalaya Mountains for the purpose of obtaining strains of pigeon peas said to grow at these elevations. Such strains will be introduced into Hawaii and hybridized with improved heavy-seeding kinds in the hope of producing a progeny that can be successfully grown at the local higher elevations.

Efforts were also directed toward furthering the banana and avocado industries. An attempt is being made to establish strains of hard-shelled avocados which will be immune to attack by the fruit fly. Because of the fly the fruit in the fresh state is restricted by quarantine regulations from being exported to the United States.

In the horticultural division tests were made with the most promising tropical and subtropical plants, including grapes, avocados, papayas, breadfruit, mangoes, Citrus, litchi, dates, and the Macadamia nut. Approximately 32,500 small plants and packages of seed of various improved varieties were distributed to local growers for trial. The horticulturist again served as chairman of the committee on fruit exhibits at the Territorial fair, which was held from September 25 to October 2, 1926, and as one of the judges of the Star-Bulletin school-garden contests. He also served as chairman of the botanical garden committee of the Pan-Pacific Research Institution.

Agronomic work was directed principally toward the introduction and development of improved field, soiling, and pasture crops upon which the dairy and livestock industries of the islands largely depend. Some progress was made in the ginger-culture experiments having for their object the development of suitable varieties for flavoring locally manufactured ginger ale. Several varieties were tested. Progress was made in the development of a solid-headed strain of lettuce for the lower altitudes where most of the truck gardens are located. The division was able to comply with practically all requests for small lots of seed and planting material of improved pasture grasses and field crops.

The agronomist, in addition to his regular duties, acted as one of the judges in the Maui public-school garden contest; continued to serve as secretary at the poultry show of the Territorial fair in 1926; was appointed chairman of the poultry committee for the Territorial fair to be held August 29 to September 5, 1927; was called upon to appraise a flock of 7,000 White Leghorns; assisted poultrymen in the selection of suitable tracts of land for poultry raising on a large scale; and otherwise devoted as much time as could be spared from the agronomic work of the station to problems arising in connection with the poultry industry. In the early part of the fiscal year he was absent from the station on a visit to the United States, where he made a study of general market problems applicable to Hawaiian conditions.

The chemical division continued to devote a large part of its time to the solution of problems arising in connection with the edible-canna industry. Improved varieties were planted, and studies were made of the insects and fungus diseases attacking the crop, and of

methods of culture, and to learn the best time of harvesting. Attention was also given to numerous problems dealing with the extraction of the starch in the mill and the final preparation for market. Two investigations were completed, one relating to the comparative composition of vegetables grown in Hawaii and on the mainland, and the other to the chemical composition of vegetables of oriental origin.

The extension agent for the island of Hawaii again devoted his energies to various agricultural problems and put producers in touch with the sources of the agricultural information they desired. He also materially assisted in extending the culture of edible canna, distributed locally grown pasture grasses and forage-crop seed, and seedling trees for windbreaks, and rendered excellent service in connection with the boys' and girls' club work, Boy Scout activities, school agricultural fairs, and school-garden contests.

Members of the boys' and girls' clubs in the Territory continue to show increased interest in their work with the introduction of improved programs. Of the 1,401 members enrolled, 76 per cent submitted reports. The activities were carried on in cooperation with the public schools and other Territorial institutions. Improvements were noted in the club records of the third and fourth year club members. Leadership activities were encouraged among the young people who had done club work for three or four years. This fall two 4-H girls from the Pollyanna and the Ivy Clubs are entering a leadership contest which is being fostered by the publishers of a farm journal on the mainland. Club members are submitting letters for publication, telling of their interest in club work and something about Hawaii, in an effort to bring the 4-H clubs of the islands in closer contact with similar clubs on the mainland. Special demonstrations and illustrated lectures were given to interested club groups.

At the Haleakala demonstration farm attention was again given to the development of agricultural practices which are best adapted to local conditions. Some 173 varieties of 81 different kinds of crops were tested. Numerous small lots of planting material were furnished to homesteaders and others for experimental purposes. Additional land was cleared and new fence systems were established.

REPORT OF THE HORTICULTURAL DIVISION

By W. T. Pope

MANGOES

Cultural experiments with the mango attracted unusual attention, probably because of the increased demand for good varieties. Among those appearing to hold special promise are the Pirie, Victoria, Whitney, Mulgoa, Number-Nine, Kalihi, Alphonse, and two hybrids, Nos. 3714 and 3715, which were produced at the station. Growers are becoming convinced of the necessity for grafting the trees for the production of choice fruit. Grafted trees assume a low spreading habit, which is of value in locations where protection is needed against strong winds, and they bear at an earlier age, probably because scion material from trees which have passed their

youth is used. Most of the varieties mentioned above have been found to be free from attack by the Mediterranean fruit fly (*Ceratitis capitata*).

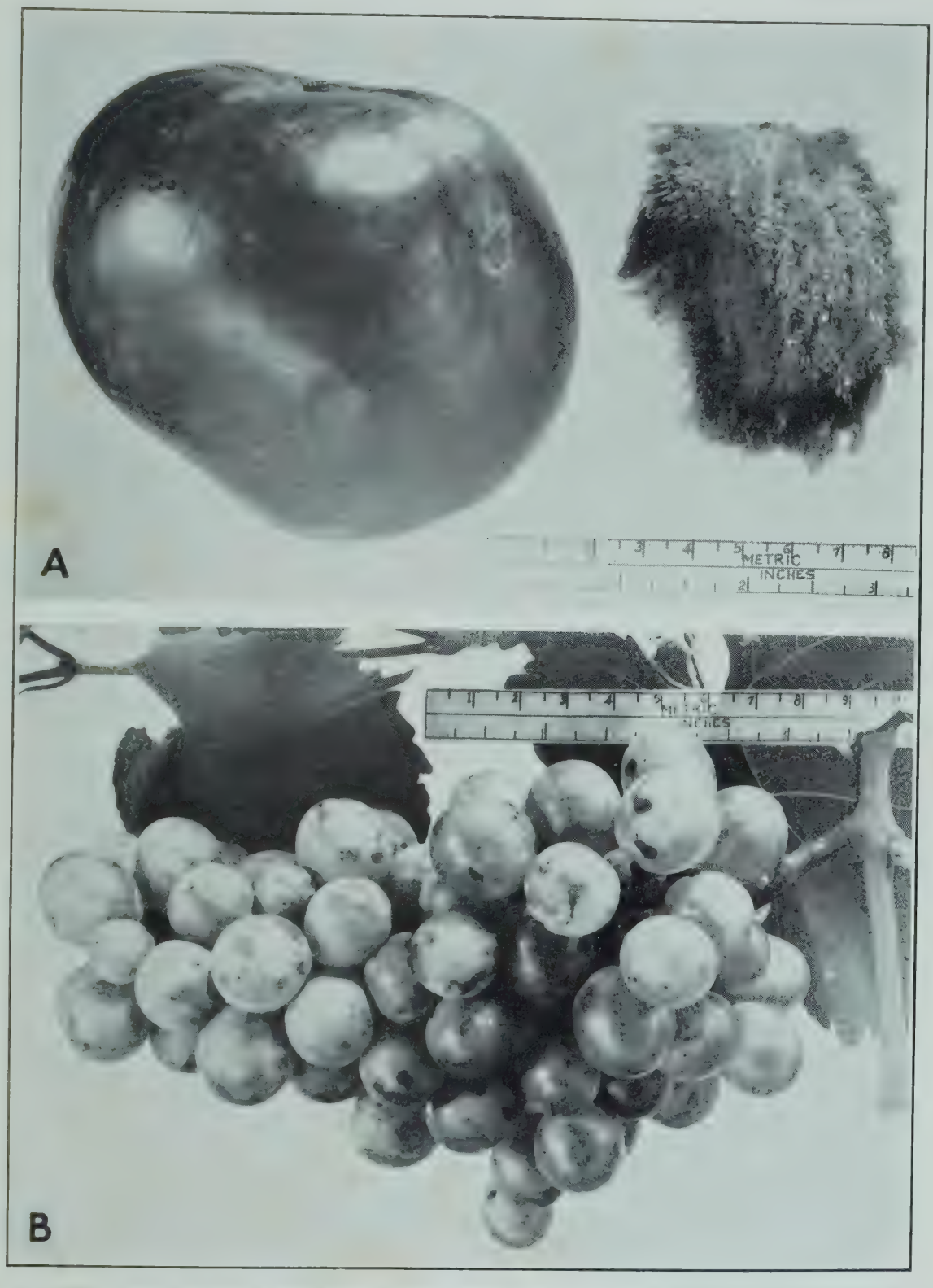
At the central station in Honolulu cultural experiments are in progress in two orchards which are located at elevations varying between 60 and 100 feet. The soil in these orchards varies from 2 to 4 feet in depth, is underlain by a somewhat porous tufa rock, and is of similar general composition. The old orchard, located in field C-IV, was started about 1908 and contains 77 trees. During the year the orchard was thoroughly plowed, planted with a cover crop, and pruned. A shortage of water for irrigation, due to the drought prevailing throughout the islands, retarded blossoming, and later frequent showers favored the development of mango blight (*Glœosporium mangiferæ*) on the blossoms and young fruit, so that a light crop resulted. On fruit of good size the fungus appears in black splotches which spread down from the stem. Spraying with Bordeaux mixture at blossom time and again when the fruit is forming tend to check the ravages of the pest. Mango trees make their best growth in localities where the wet season is over before blossoming time begins. In the past the orchard has been a valuable source of graft wood, but this season good propagating material was rather hard to get.

The young mango orchard, located in field B–III, was started in November, 1923, and contains 43 trees. The trees are being grown alternately 30 feet apart in three rows so as to form a windbreak on the northeast side of the citrus orchard. The mango tree is more resistant to wind than are most of the other tropical fruit trees in Hawaii. Two years ago the orchard was interplanted with two rows of papayas 8 feet apart between rows of mangoes with tomato plants 4 feet apart in the spaces remaining. The tomatoes were not grown this year, but the papayas are to remain for another season at least. The young mango orchard now contains 14 varieties, most of which are comparatively new and will be of value as a source of propagating material for grafting experiments. The orchard was pruned, sprayed, and cultivated.

In the mango-propagation experiments seedlings were grown, and several methods of grafting were tried, including side-tongue grafting, wedge grafting, and bark grafting, all of which gave in nearly every instance very gratifying results. Tests with seeds of the Pirie mango, an East Indian variety, were unusually satisfactory presumably because it produces only one plant from each seed. The seedlings apparently are larger and more vigorous than those from the polyembryonic seed of some other varieties often used. This character, however, requires further investigation.

Varieties newly established at the station include the Bishop, Steward, Farrar, Ludwig, Ono, Waterhouse, and Larnach. (Pl. 1, A.) The Larnach, a seedling of unknown origin, was planted in the residence yard of No. 1946 Makiki Street, Honolulu, about 1910. The place became the property of A. D. Larnach about 1920. The tree soon came into fruit and has borne freely nearly every year since. The fruit has attracted considerable attention. On July 12, 1926, specimens were photographed and described at the central station, and the variety was designated station accession No. 5155.

PLATE 1



A.—The Larmach mango, a newly established variety at the station. Fruit very attractive and of good flavor. Seed at right. B.—Malaga grapes grown at the station. Scions from California were grafted on Isabella rootstocks

A.—Bountiful avocado, a new hybrid fruiting for the first time in December, 1926. Developed by W. J. Cooper, Hauula, Oahu. B.—Wild seedling cherimoyas, showing variations in the fruit. Weight from 1½ to 2 pounds; quality good. Introduced into Hawaii early in the nineteenth century

The Larnach mango is very large, has a total weight of 15¾ ounces, and is oblique to round in shape; length from stem to apex, 3⅝ inches, width, 4½ inches, thickness, 3¼ inches; deep depression around stem, the cavity having grooves radiating from the stem; ground color, yellow with bright red over top and over most of the exposed side; rind, thick and leathery; flesh, yellow to light yellow, somewhat fibrous, firm, juicy, with apricot flavor; keeping qualities good.

The station, working in cooperation with interested growers, has been instrumental in establishing nearly 300 grafted trees in the Territory.

GRAPES

Experimental work with grapes was largely a continuation of that begun in 1921. The original vineyard of 200 Isabella vines was

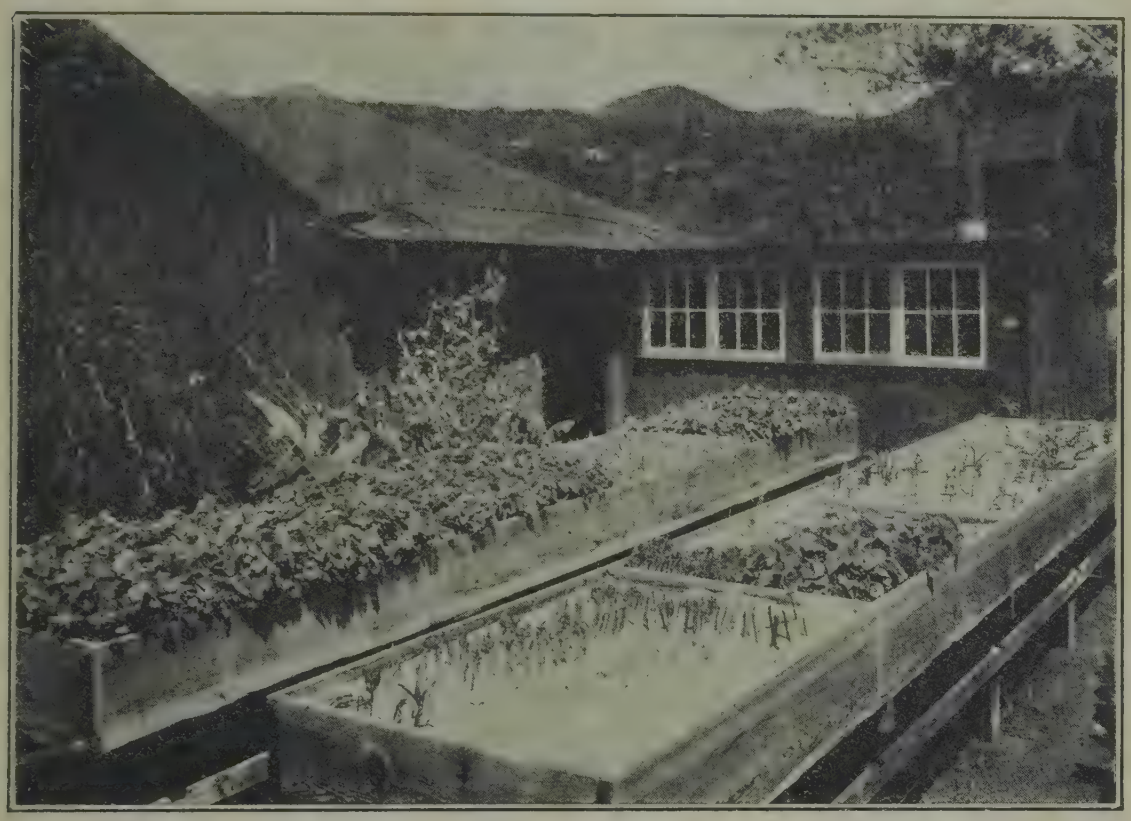


FIG. 1.—Grape cuttings at the station, rooted in large sand boxes in the open. The cuttings were set in the sand immediately following pruning of the vines during the dormant period

maintained as in other years to supply resistant roots upon which to graft other strains and for making cultural tests. Plants of the varieties *Vitis labrusca* and *V. vinifera* which were grafted on Isabella stocks have fruited. The Isabella fruits on its own roots. Two plants of the variety *V. tiliæfolia* (S. P. I. No. 44060), obtained in 1921, have fruited. California varieties which were grown on their own roots have been attacked by nematodes in the soil to such an extent as to suggest the advisability of growing these varieties on Isabella rootstocks. Varieties of recent introduction fruiting for the first time include the Duchess, Malaga (pl. 1, B), Cornichon, and Rose of Peru. Varieties which were introduced from southern California during the year include the Olivette Blanche, Gros Guilliaume, and Pierce. These varieties are making good growth and show considerable promise.

An experiment occupying an acre of ground is being carried on in cooperation with a homesteader on Molokai. It is planned to establish the Isabella variety, and after the vines have made several years' growth to top-work a part of them to other good table varieties. Interested growers who are making tests with grapes on a small scale received a limited number of vines, amounting in all to about 600 plants. (Fig. 1.)

Several conclusions have already been reached in connection with the grape experiments. To grow grapes successfully the varieties should be grafted on Isabella rootstocks, and the so-called Japanese beetle (*Adoretus sinicus*) must be kept under control.

AVOCADOS

In the cultivation of the avocado in Hawaii probably the most important problem awaiting solution is the development of more effective methods of propagating good varieties. Vegetative methods of propagation have not been so successful with the avocado as with the mango and the Citrus. Last year the greatest success with the avocado was had through wedge grafting, utilizing seedlings 40 to 50 days from date of planting the seeds. This year, at the time some 600 seedlings were ready for wedge grafting, dry weather prevented the development of the young shoots for use as scions. The station orchard is located at the Tantalus substation, where irrigation is not possible. The seedling stock was grafted much later in the season, however, when the wood was larger and harder. Several methods of grafting were employed at different times on seedlings grown from seed in gallon tin containers and varying in height from 1 to 2½ feet. The side-tongue method of grafting was used, the insertion being made a few inches above the soil. In both the wedge-grafting and the bark-grafting methods the seedling was cut off about 5 to 8 inches above the ground. If the scion fails to grow the seedling is lost. With the side-tongue method of propagating avocado trees the seedling survives and may be tried with a new graft in the course of a few days if the scion and the stock fail to unite. In all the unions melted paraffin was found to be of benefit as a protective covering. Amateur nurserymen have experienced difficulty in producing grafted stock of choice varieties. Although a fair percentage of the seedlings in Hawaii tend to produce good fruit for commercial purposes, the standard varieties evidently must be vegetatively propagated.

A few new varieties were added to the cultural test under way at the Tantalus substation, where the elevation is about 1,000 feet and climatic and soil conditions are better than at the central station. The trees are set in terraces. Most of the trees are over 9 years old and with the exception of a few later plantings have already shown the habits and nature of fruit of the particular varieties from which they were grafted. The fruit set the spring of 1927 was abundant and has received ample moisture from the frequent rains to insure maturity. Bountiful (station accession No. 5317) is an excellent new variety of the year. (Pl. 2, A.) The result of a cross between Guatemalan and West Indian, this hybrid fruited in December, 1926, while very young. The tree is very vigorous and prolific and was grown by W. J. Cooper, of Hauula, Oahu.

The Bountiful is large, almost spherical in shape, and weighs 2 pounds; surface, slightly undulated and of a greenish color with slight cast of yellow at maturity; rind, medium to thick; pulp, light greenish yellow, buttery, without fiber; flavor, very good; seed, tight in cavity; weight of seed, 4½ ounces; weight of rind, 4 ounces.

PAPAYAS

The papaya investigations, representing 13 different kinds, were conducted in fields C–II and C–III, which are located in different parts of the station grounds. The papayas are not designated by varietal names since they are not true varieties, but are known by accession numbers. Usually the labels contain a suggestive name also, such as long-fruited type, round-fruited type, Dapitan, Solo, Guam, or Samoa. The seeds were planted in propagating trays filled with coral sand, and the resulting seedlings were transplanted 20 days later to 4-inch containers, where they remained for about 60 days prior to transplanting to the field. The total number of seedling trees set was 214, and the percentage of staminate trees among dioecious kinds averaged little less than 10 per cent. The first fruit to ripen was of dioecious type, round form, and weighed a little over 6 pounds. The fruit was of good quality and matured in 330 days after planting the seed producing the tree.

In another experiment begun in field B–III in 1925 with 185 seedlings from the seeds of one papaya tree, the trees came into bearing in May, 1926, and have been producing almost constantly since. The original tree bore fruit of oblong-oval shape, with flesh of deep crimson color and fine flavor. None of the trees in the experiment have borne fruit of crimson color. Three per cent of the fruits have been pinkish or pale red and the rest yellow to orange.

Young papaya plants which are grown in the open in the full sunlight for 60 to 90 days may be successfully shipped by mail or by freight to distances requiring 10 to 12 days in transit. In preparing plants for shipment the roots should be carefully washed to remove all adhering soil and then packed in dampened (not wet) sphagnum moss. The plants should be wrapped in waxed or oiled paper, including even the sphagnum-covered roots, and then in turn with corrugated pasteboard to maintain the shape of the package, and finally in manila paper of medium weight.

Several cooperative experiments in papaya growing were started, and 14,000 plants from selected stock were distributed throughout the Territory. During the year the station obtained papaya seed from Tahiti, Samoa, and Guam, and from Natal and Tanganyika in Africa.

BREADFRUIT

The breadfruit experiment in progress is a continuation of that begun three years ago, and is being carried on in cooperation with G. P. Wilder, of the Bishop Museum staff, who is visiting in the South Sea Islands. In addition to the establishing of improved varieties in Hawaii, studies are being made to determine the best methods of collecting, packing, shipping, and propagating the breadfruit. The propagating material consisted wholly of cuttings taken from the surface roots of seedless varieties. Five consignments of

material have been received to date. The material was assembled at Papeete, Tahiti, Society Islands, and shipped via San Francisco to Honolulu. The roots were in transit from 20 to 30 days and in some instances were out of soil for a much longer period. A report concerning seasonal conditions prevailing at the time collection was made has not as yet been received, but since only a very small percentage of the cuttings rooted and sprouted as compared with the percentage of those received from Samoa last year that rooted and sprouted, it is thought that either the period required for transit is too long for breadfruit or that collection was made during a season when the cuttings could not withstand shipment.

Young seedless breadfruit trees at the station have been successfully propagated from the surface roots of old Hawaiian trees for the past several years. The methods followed in the present experiment were carefully worked out. The propagating bench is located in the insect-proof, glass-covered house where both temperature and moisture can be controlled. A 2-inch layer of loose, rich, sterilized potting soil was placed in the propagating bed and overlain by a 1-inch layer of washed coral sand. The soil was slightly firmed, and the cuttings were placed horizontally and covered with more sand to a depth of 4 inches. This 7-inch medium was then firmed to give close contact between sand and cuttings. From three to five months are required by breadfruit cuttings to develop sprouts and new fibrous roots of sufficient size to permit transplanting from the propagating bed.

The results of the present experiment tend to confirm those obtained in 1923 and 1924. The so-called surface roots must be carefully removed from the soil during the dormant period immediately preceding the renewal of growth. The cuttings should vary from 1 to 1¾ inches in diameter and be cut in 12-inch lengths for shipping. Prior to planting the cuttings should be sawed in 6-inch lengths and the ends smoothed with a sharp knife.

CITRUS FRUITS

Cultural tests with citrus-fruit trees have been in progress at the central station in Honolulu for some years. The work varied little from that of last year. A few new kinds of citrus were added, and the orchard was thoroughly pruned and cultivated. A cover crop of cowpeas is being grown and will be plowed under to improve the soil. The orchard in general has not recovered from the ill effects of the droughts of the last several years. Orange scale, mealybugs, and aphids attacked the trees during the year and were brought under control by spraying and by the recent rains. Tree cockroaches have lately appeared in considerable numbers and damaged the trees by girdling the bark of the twigs. As a control measure tin cans containing a poisoned bait and open only sufficiently to admit the pest have been tied among the twigs.

In connection with the cultural test, attention is directed to the occasional occurrence of abundance of seed in the Washington Navel, Golden Buckeye Navel, and Thomson, varieties of orange which are normally seedless. This phenomenon has also been observed in the Marsh Seedless and the Foster grapefruits, and in the Victoria shaddock. (Pl. 3, A.) The fruiting season extends over several

A.—Victoria shaddock, a pink-fleshed fruit grown at the station. Excellent for salad making. B.—Shaddock seedling, 6 months old. Notice the freak blossom corolla modifications on bracts and parts of true leaves

months, but the seeds were noted only on the fruits ripening during a period of two or three weeks on two occasions during the past six years. The trees grow at no great distance from lemon, lime, orange, and other kinds of citrus trees known to have fertile pollen. Isolated trees of the Victoria shaddock and the navel orange from the same source of grafting material as the above-mentioned trees have not been observed to bear seed-containing fruit.

Another interesting occurrence was the abnormal flowering of young shaddock trees (*Citrus decumana*). (Pl. 3, B.) In a recent experiment with rootstocks, a number of seedlings 10 to 12 inches high began to blossom at about six months of age. All the leaves on the upper part of the stem were in part corolla-like. The lower ones had white margins; higher up, half or more of each leaf was petal-like in structure; and near the flower the entire leafage and the stem were petal-like structures. The flower crowning the stem seemed to be perfect but failed to set fruit.

Citrus-fruit trees have been propagated at the station from seed and by grafting. The seeds were germinated in shallow boxes or flats containing coral sand, and the resulting seedlings were transplanted to containers of sterilized soil. Three hundred seedlings of the Hawaiian orange were grown to permit a study of the amount and kind of variation occurring in the fruit. Seedlings from the seed of the Hawaiian orange generally tend to produce fruit of fairly good quality, but exhibiting some variation. Fifty seeds from the navel orange were germinated to study the development of the seedling into bearing trees.

Other seedlings which were grown for use as propagating material included 28 sweet-shaddock plants, 116 common-shaddock plants, 50 trifoliate-orange plants, 200 tabog plants, and 378 sour-orange plants. Six hundred lime seedlings were grown for use in cooperative cultural tests.

MACADAMIA NUT

Interest in Macadamia-nut culture increased considerably during the year, more because of the results of experiments which are being carried on in cooperation with private growers using 50 or more trees each, than because of the distribution of small numbers of trees for home planting. The seed and trees are in great demand. The station received from Queensland, Australia, a small lot of the seed of two varieties of *Macadamia ternifolia* and seed of *M. prealta*. The nuts of one of the varieties of *M. ternifolia* were large and of comparatively thin shell. All the nuts obtained failed to germinate.

Approximately 800 seedlings were grown from selected Macadamia nuts of the two old trees at the Tantalus substation, and 1,200 seedlings from seed obtained from other sources. About three-fourths of the seedlings were distributed.

The small grove of 50 trees planted at the Tantalus substation in 1921 has grown unusually tall, and the trees have suffered considerably from strong winds. Tall Macadamia trees growing in other parts of the Territory have been similarly affected. The experiments begun three years ago in cooperation with T. C. White, to learn the effect of pruning on Macadamia trees under Kona conditions, are expected to show some interesting results. An inspection of the

plantation of the Hawaii Macadamia Nut Co., where 6,000 Macadamia trees have been planted at different elevations ranging from 1,100 to 2,700 feet, shows that the location is favorable to the culture of this nut.

A mimeographed circular giving information on Macadamia nut culture was prepared for distribution.

BANANAS

Investigations made to determine the cultural and commercial possibilities of the banana were completed and the results submitted for publication.[1] Experiments both at the central station in Honolulu and at the Tantalus substation are being continued for the purpose of supplying propagating material for further work and for distribution to interested growers.

Plantings of the Brazilian variety have greatly increased within the last two years. Over 100 additional acres were devoted to the crop on windward Oahu this year. Propagating material of the Bluefields variety is much more abundant than formerly, and the planting of Chinese varieties by regular growers is increasing, probably on account of the unusually good prices which are paid for the fruit in the markets of the Pacific coast. The Hawaiian banana is in greater demand for home consumption than in previous years. This, too, has brought about an extension in the area devoted to the crop, particularly on the island of Hawaii, where the native varieties make their best growth.

DATES

The development in various parts of the Territory of date trees bearing fruit of fairly good quality from the seed of fruit which was purchased in the local markets has stimulated interest in date growing. Among the introductions of the year from the Indio experiment station, Indio, Calif., were 100 each of the varieties Deglet Noor and Maktoom, and 50 each of the varieties Manakhir, Tazizaoot, Saidy, Barhi, Khalasa, Zehedy, Halawy, Thoory, and Deglet Noor-Canariensis hybrids.

COFFEE

Some investigations were carried on with coffee, and notes from publications and many references were collected. A survey of the coffee situation in the district of Kona, Hawaii, was made during one week of August, 1926. Material is now being collected and methods are being outlined for an experiment which it is hoped may be started early in the fiscal year, 1928.

A few coffee trees of *Coffea arabica* and *C. robusta*, which were planted at the Tantalus substation about 1902 and 1903, produced light crops during the year. Some 1,200 young plants are now growing from the seeds of *C. arabica* which were obtained from the Tantalus substation trees. Seeds were also distributed to cooperative growers desiring to grow coffee on a small scale. Coffee seeds which were planted in January, 1927, in flats containing a mixture of soil and coral sand produced seedlings which reached suitable

[1] POPE, W. T. BANANA CULTURE IN HAWAII. Hawaii Agr. Expt. Sta. Bul. 55, 48 p., illus. 1926.

size for transplanting to pots in April. Sample packages of *C. arabica*, *C. bukobensis*, *C. excelsa*, *C. liberica*, *C. quilloa*, and *C. robusta* were sent to the station for trial by R. T. Rogers, head gardener of the Amani Research Institute, Amani, Tanganyika Territory, Africa.

The six varieties on arrival were held by the Bureau of Plant Inspection in Honolulu, and later forwarded to the Bureau of Plant Industry, United States Department of Agriculture, at Washington, D. C., where they are to be grown in quarantine.

Coffee investigations in Kona showed that most of the lands under cultivation by small growers are leased from large landowners. In many cases the leases cover a period of 10 years or longer, and some of the landowners are not interested in either the welfare of the small grower or the coffee industry. In most cases the growers know very little concerning agricultural practices in general and practically nothing concerning coffee growing in particular. They seldom come in contact with agricultural experts, and some of them are inclined to look upon offers of assistance with suspicion. The coffee trees are sometimes badly infested with aphids, and little effort is made to control the pest; growers remove crops year after year with little attempt to maintain soil fertility; fields or parts of fields are abandoned presumably because of poor yields, and coffee growers are found devoting most of their time to other activities. Considerable areas of land which are not now utilized for crop production could be profitably planted with coffee. Thousands of acres of land in Kona alone are overgrown with guava bushes and should be cleared for coffee production. The area is admirably adapted to coffee. The country slopes to the westward, with high mountains in the east and northeast which afford shelter from the prevailing trade winds. The rainfall is abundant and is peculiarly regulated by the mountain formations. The so-called rainy season occurs from May to September, which is also the season of highest temperature. The clouds form in the early afternoon, and the rain begins about 3 or 4 o'clock and continues without wind into the night. The formation of clouds during the time of day when the sun is hottest affords a natural protection for coffee trees, which in most places must be shielded against the sun's rays by the interplanting of shade trees. The coffee plant is rather delicate in its relation to extreme temperatures in the Hawaiian Islands. The soil of Kona is a rich lava which overlies a coarse stratum permitting the excellent underdrainage so essential for coffee growing.

These favorable conditions have demonstrated their value for the production of coffee of high grade in Kona. A consideration of the conditions and also of the comparatively high prices paid to growers for the crop should serve to encourage interested growers to pursue a scientific study to improve the industry and follow agricultural methods permitting the most profitable production of coffee. Plans have been made for cooperative work in Kona for the purpose of investigating the coffee and such other agricultural crops as may be found adapted to the region.

FIGS

Fig experiments were confined to cultural tests and the propagation of new plants from cuttings. The four varieties of figs which are growing in the station orchard fruited heavily, particularly the

Kadota which has proved to be a prolific bearer in Hawaii. Most of the propagating material used in the experiments was from prunings which were obtained from cooperative growers. About 600 fig cuttings were rooted and distributed.

CHERIMOYA

In Hawaii the cherimoya (*Annona cherimola*) grows at elevations above 1,000 feet where the climate is cool and comparatively dry during the greater part of the year. Such conditions are to be found in parts of the islands of Maui and Hawaii. In Hawaii the cherimoya now grows wild as a part of the natural vegetation. Some 200 seedlings were grown from the seed of selected fruits which were collected from the Kona district. Many of these seedlings were distributed to interested growers. It is planned to conduct certain grafting experiments, using scions from trees of unusual quality, in the hope of establishing standard varieties for localities which are adapted to cherimoya culture. The cherimoya should find a ready local market if the fruit is produced in reasonable quantities. (Pl. 2, B.)

MULBERRY

There is constant demand for the black mulberry which has been in cultivation in Hawaii for many years. The tree is a prolific bearer and is easily propagated from cuttings. Some 2,000 cuttings were distributed.

ROSELLE

The roselle is considerably in demand for jam and jelly making. New seeds of two varieties which were obtained two years ago have been propagated. Approximately 2,000 plants of the roselle were distributed during the year.

MISCELLANEOUS NOTES

Other economic plants receiving attention included the litchi, star apple, tomato, mountain apple, carambola, chestnut, pecan, sapodilla, cashew, guava, pitanga, carissa, Brazilian cherry, sea grape, soursop, tree tomato, watermelon, granadilla, and Pejibaye palm.

One hundred and seventy-six introductions, consisting principally of seeds, cuttings, and rooted plants, from various parts of the world were made during the year. The more important introductions included grapes (3 varieties), dates (11 varieties), mangoes, coconuts, breadfruit varieties from the South Seas, and a superior variety of pecan from Georgia.

Approximately 32,500 new and improved plants, packets of seeds, cuttings, graft wood, and rooted plants were distributed, including 400 grafted trees of new varieties of avocados, mangoes, and Citrus varieties.

Cooperative experiments were conducted in the Macadamia nut groves of C. T. White, Kealakekua, Hawaii, W. L. Hopper, Wahiawa, Oahu, and R. J. H. Farrar, Pupukea, Oahu; the avocado orchards of C. Miller, Kaneohe, Oahu, and D. S. Bowman, Kona, Hawaii; the mango and avocado orchards of W. J. Cooper, Hauula, Oahu; the

papaya groves of D. C. Pak, Palolo Valley, Oahu, E. Y. Chang, Kaalaeu, Oahu, and T. Okomoto, Waialae, Oahu; the grape vineyard of G. Nihoa, Molokai; the date garden of E. P. Fogarty, Waiahae, Oahu; and in connection with banana and other fruit growing by Charles Dole, Kapaa, Kauai.

The larger cooperative experiments constitute an endeavor to assist interested persons to get a start in the fruit-growing industry. The horticultural department responded to many requests for information from growers, prepared for distribution mimeographed circulars on the roselle, the Macadamia nut, and insect-pest control, and gave horticultural demonstrations to classes and other interested groups. The horticulturist acted as judge in the Oahu school-garden contest of 22 schools and 290 home gardens. He made three trips to each garden during the spring. The schools made a creditable exhibit of fruits and vegetables at the Pan-Pacific Conferences on Education, Reclamation, and Recreation, which were held in April, 1927.

REPORT OF THE AGRONOMY DIVISION

By H. L. Chung

EDIBLE CANNA

In view of the potential importance of edible canna as a commercial source of starch in Hawaii, a further effort was made to increase production by selecting the best hills for seed and to develop good varieties by cross-breeding. Two interesting and promising hybrids were found among the seedlings resulting from crosses made last year. One has green corms in striking contrast with the corms of the parent which are purple. A large area has been planted with seedlings of the two hybrids, both at the station and at the Haleakala demonstration farm on Maui.

An investigation was made to determine the most practical method of treating the hard coat of the canna seed prior to planting in order to hasten germination. Ordinarily the seed is filed to scarify it, but the method is slow and laborious. Commercial sulphuric acid was therefore used to soften the seed coat.

SWEET POTATOES

The sweet-potato seedlings and a number of standard varieties were subjected to a rigorous culling test, and only the best were retained for further breeding work. The flower-bearing varieties were studied to determine the relation of blooming to productivity and earliness. The results of preliminary tests fail to show that blooming affects either productivity or earliness.

TARO

A cultural and variety test was made to determine the comparative yields and keeping qualities of a Samoan variety and a number of choice Hawaiian varieties of taro. Tests were also made with three varieties of dry-land taro which represent the best obtainable in the local market and find a ready market on the mainland. The

varieties of upland taro give promise of becoming a valuable crop for Hawaii.

WHITE POTATOES

An extensive potato-planting experiment was started in cooperation with growers in the Palolo Valley, but the crop was a failure, on account of heavy rains and wind. It is planned to repeat the experiment in the fall of 1927.

GINGER

The ginger plantings were also destroyed by heavy rains and by insect pests. The station has encouraged the growing of this crop to meet the demand for island-grown ginger for use in the manufacture of ginger ale.

CORN

A preliminary study was made of the Guam corn hybrids, and an attempt was made to establish varieties having sturdy, heavy ear-bearing stalks and other outstanding characters. Encouraging results were had in the work of improving the varieties of Guam, Cuban Red, and sweet corn.

SORGHUM

The past year was very favorable for the growing of grain sorghums, and was conspicuous by the absence of insect pests. Seedlings from seed taken from plants which grew in the agronomy field under adverse conditions made remarkable stands.

LETTUCE BREEDING

Approximately 220 crosses were made in the lettuce-breeding work. Some very interesting and promising individual head-lettuce plants have been produced. An attempt is being made to establish varieties having desirable characters.

FORAGE GRASSES

Fourteen species of forage grasses were successfully maintained in the demonstration plats and the yields were recorded at each harvest. Propagating material from the areas was distributed to ranchmen and to dairymen who are interested in the grasses.

EDIBLE-POD PEA

Three varieties of edible-pod pea were obtained by the junior agronomist and grown to compare their adaptability, quality, and yield with a local established variety. Of the three, one promises to be outstanding. Edible-pod pea is regarded as a luxury in the local market, and usually retails at 65 cents per pound.

PLANTING WINDBREAKS

Many inquiries for information concerning the varieties suitable for temporary windbreaks were received from homesteaders in

localities where the winds damage the crops. The agronomist recommended the *Crotalaria usaramœnsis* and the pigeon pea for the purpose. Napier grass, Uba cane, sunn hemp, and panax hedge were grown in an experiment to determine their relative desirability as windbreaks and their rate of growth.

NEMATODE CONTROL

A part of the agronomy field which was found to be infested with nematodes was planted with tomato plants for use as indicators of the amount of infestation, and with tobacco plants to determine their toxic effects upon the worms. The effect of the tobacco plants upon yield of tomatoes was also noted.

SEED FUMIGANTS

Moth balls were used on a large scale as an effective fumigant, and a test with moth balls and carbon bisulphide was made comparing their effectiveness, cost, and ease of handling.

Records are kept of the ages of all seed produced at the station, and notes are made concerning the rate of deterioration.

DISTRIBUTION OF SEEDS AND CUTTINGS

Distribution of seeds and cuttings from July 1, 1926, to June 30, 1927, was made in amounts as shown in Table 1.

TABLE 1.—*Seeds and cuttings distributed during the fiscal year ended June 30, 1927*

Crop	Seed	Cuttings	Crop	Seed	Cuttings
	Pounds	*Number*		*Pounds*	*Number*
Alfalfa	15		Pigeon peas	20	
Beans	170		Spinach	4	
Jack beans	4		Sunflower	1	
Mungo beans	4		Sunn hemp	12	
Velvet beans	16		Jerusalem artichokes		60
Chinese cabbage	1		Cassava		200
Guam corn	200		Edible canna tubers		350
Sweet corn	50		Ginger		50
Cowpeas	40		Grasses		9,500
Grasses	4		Napier grass		24,000
Lettuce	6		Potatoes		20
Melons	3		Sweet potatoes		6,000
Peanuts	90		Uba cane		2,800

REPORT OF THE CHEMICAL DIVISION

By J. C. RIPPERTON

EDIBLE-CANNA INVESTIGATIONS

Progress was made in the commercial development of the edible-canna starch industry notwithstanding the drawbacks incident to the establishment of the new industry. The exceptional yields and hardiness of the crop, particularly in the Waimea district, lend encouragement to the belief that the crop will ultimately be established upon a firm basis.

Correspondence was carried on with growers in various parts of the Tropics and sub-Tropics to learn to what extent edible canna

is grown in these parts of the world. From Queensland, Australia, it was reported that the principal canna-producing area is at 27° south latitude and that the crop is not grown any nearer the Equator than 15° south latitude. Hawaii lies between 19° and 23° north latitude.

Under tropical conditions such as exist in Java, the canna has been abandoned in favor of the higher-yielding cassava. In the continental United States small plantings in Florida showed little promise. The average yield in Queensland, where edible canna has been grown for starch for nearly 50 years, is not over 10 tons in 12 months. Under the ideal conditions existing in Waimea, Hawaii, the crop usually yields 30 tons per acre in 15 months. It is felt, therefore, that edible canna is unusually well adapted to the climate of the Hawaiian Islands and should be able to compete

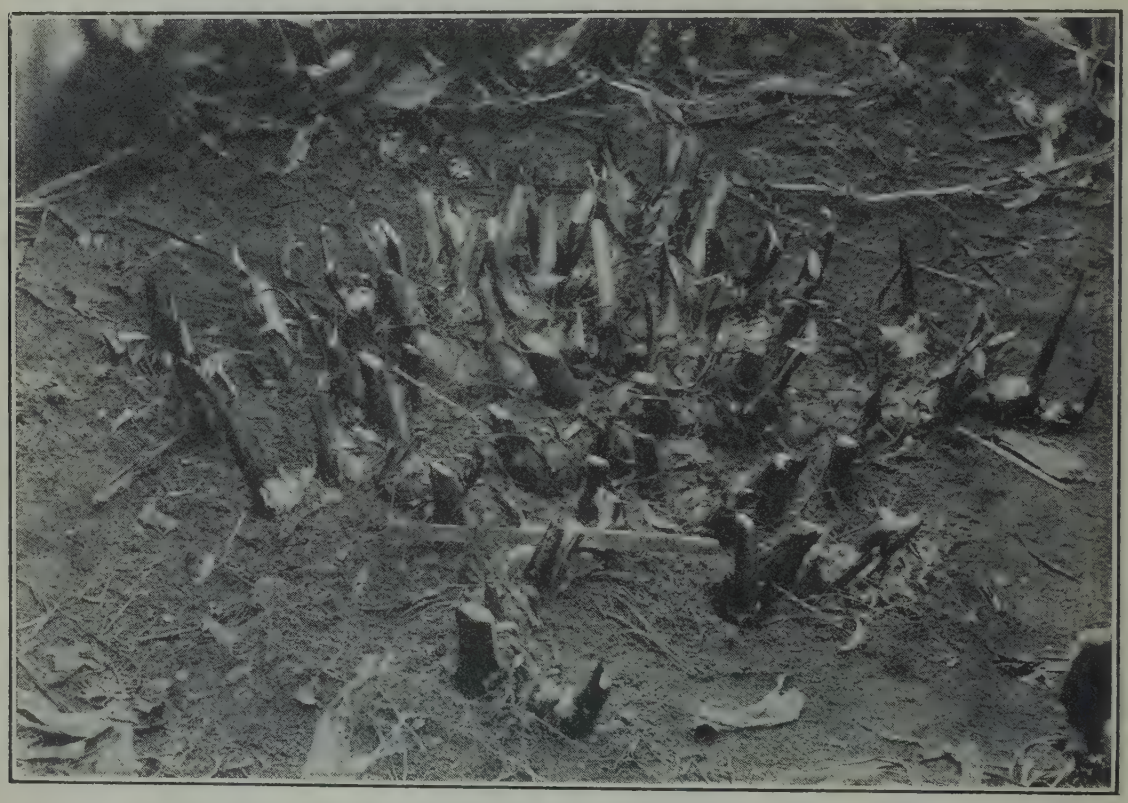


FIG. 2.—A 35-pound hill of edible-canna rootstocks grown at Laupahoehoe, Hawaii

successfully on the market with edible-canna starch from other countries.

Considerable interest is being shown in the possible utilization of edible canna by the established agricultural industries of the Territory. If the top growth of the plant can be used as a green manure in pineapple culture and the rootstocks for starch or as a stock feed the crop might profitably be grown in rotation with pineapples. The possibility of growing edible canna on pineapple wilt-infested areas or on lands that are not adapted to the pineapple or sugar-cane crops is under consideration. Edible canna would seem to be especially desirable for homesteaders in the Waimea district, because the crop as a starch-producing plant can readily be converted into cash, and it can also be used as a feed for stock. The station is endeavoring to stress the advisability of adding to the Territory a third agricultural industry which can be rapidly expanded in the

event of failure overtaking either of the two leading industries. (Figs. 2 and 3.)

FIELD EXPERIMENTS

An experiment occupying half an acre of land was established in Waimea in August, 1926, to study problems of improvement in the strain through seedlings, hybridization, mass selection, and mutation. The work is being extended for the purpose of determining the effect of seed selection on resulting seedlings and the best cultural practices for the plant; of testing a number of introduced varieties to learn their adaptability to Hawaiian conditions; of finding the cause of and the remedy for the appearance of diseased and abnormal plants in an otherwise sound field; and of studying the methods of growth of the canna plant.

Harvesting in the fertilized experimental plats begun in October, 1924, was deferred, due to difficulties in the milling process. Monthly

FIG. 3.—A typical example of an abandoned homestead area, Ahualoa, Hawaii. Part of this land seems to be well adapted to edible-canna growing

harvests of 0.1-acre plats of one-seed and two-seed plantings were begun at the tenth month. The experiment has for its purpose the determination of the progressive increments in yields of rootstocks and the best age at which to harvest the crop. A systematic study of the growth in the field by the classification method is being conducted in connection with the harvests. To determine the progressive increase in the starch content of the rootstocks, specific-gravity measurements on the rootstocks were made from time to time. In this experiment, as in previous experiments, the yields were unusually high. The crop when harvested at the end of the fourteenth month was found to have produced at the rate of 33 tons of rootstocks per acre.

At the central station in Honolulu an experiment was begun to study the growth of the plant in the greenhouse under more carefully controlled conditions than is possible in the field. Progressive growth of the plants is being recorded by means of tags which are

attached to each spike and stalk as they appear. A small area at the Tantalus substation, where climatic and soil conditions are well adapted to the growing of edible canna, was planted, and growth is being studied by biweekly tagging of the newly developed stalks.

In the agronomy field a continuous experiment in hill selection was begun. Two tubers were selected from each individual hill for planting, one being a first-generation rootstock and the other an immature rootstock of the fifth or sixth generation. It is planned to repeat the process twice, making a total of three plantings, before hill selection is begun. Planting stock from Porto Rico and from Queensland, Australia, was received and planted, and arrangements were made to obtain stock from the wild species in Peru, where the canna plant is said to have originated.

MANUFACTURING PROCESS

The chemist and the extension agent for the island of Hawaii spent two weeks investigating the process of manufacture of edible-canna starch at a factory in Waimea, Hawaii. The manufactured product was excellent in quality, but the method used showed a number of defects. A report concerning the defects and suggested remedies for them was submitted to the company. It was pointed out that the manufacture of edible-canna starch is different from that of other starches in at least two respects. One concerns the washing process and the other the fibrous nature of the rootstocks. The long roots, dead scales, and cracked surface of the rootstocks make it extremely difficult to cleanse them of adhering soil. The shredded pulp of the edible canna is light and fluffy, whereas the pulps of the potato and the cassava resemble a sludge. When the light pulp of the canna is thrown on the extraction screens the excess water runs through quickly and leaves the pulp comparatively dry. With the denser pulps of the potato and the cassava, however, the water passes through the screens much more slowly. Extraction is very incomplete in the first instance, whereas it continues throughout the length of the screen in the second. Starch-extraction methods will have to be modified somewhat for edible canna before they can be expected to give satisfactory results. The manufacturing concern was advised to purchase a standard potato shredder because the present machinery results in only incomplete rupturing of the cell structure of the rootstocks, which is one of the principal causes of low extraction. Correspondence was carried on with a number of manufacturers of starch-extraction machinery in Germany and France in the hope of eventually having introduced into Hawaii up-to-date machinery which will be more effective in overcoming the difficulties incident to starch manufacture than are the locally manufactured machines.

MILL-CONTROL METHODS

Some beginning was made in the establishment of a system for control in the milling process. An adaptation of the procedure used in sugar-mill control was worked out to determine the extraction. Determination of the starch content of the incoming rootstocks by the specific-gravity method seems to be feasible for the purpose.

The so-called "spot test," which was developed by the station, promises to be particularly useful in the refining process. By this "spot test" method a weighed portion of the wet starch undergoing refinement is hydrolyzed and the particles of soil and darkened tissue settling out are collected on a disk of filter paper. Inspection of these disks indicates definitely and promptly when the refining process has gone far enough. A rapid method of determining the moisture content of starch in the drier has been developed and found useful.

STARCH-EVALUATION METHODS

Study was continued of the methods of determining the viscosity of the finished product, and the methods previously developed were considerably changed, particularly in regard to temperature and to time of cooking. The temperature of cooking was reduced from 90° or 95° C. to 80° and the time from 30 minutes to 15 minutes. Prolonged cooking at higher temperatures caused uncertain losses in viscosity. These changes, coupled with certain refinements in technic, should make the method dependable. The Saybold standard viscosimeter, the MacMichael viscosimeter, and a simple pipette viscosimeter devised by the station for the purpose, are among the instruments being tested for viscosity determination.

A modification of the previously described "spot test" has proved to be adapted for use in starch evaluation. The test consists in hydrolyzing a weighed portion of the dry starch which is ready for shipment. The soil and the dark tissue are collected on a hardened filter paper. After being dried, the particles are mounted with balsam on a microscopic slide. The slide forms a permanent record of the shipment and permits comparison with a "spot range" so that the lot can be graded according to purity. Chemical methods for determining such impurities as protein, ash, and fiber have been outlined, but will hardly be needed in actual practice.

SOME FACTORS AFFECTING THE PROPERTIES OF CANNA STARCH

Work begun in 1926 to determine the effect of various factors on the properties of canna starch was continued, and conclusions of immediate value to the industry have been reached. Even extreme variations in the amount of rainfall were found to have little effect on the starch. Age has little effect so long as the rootstocks have not begun to deteriorate. With deterioration in the older rootstocks a loss in viscosity occurs in the starch, and climate has a decided effect. Starch from rootstocks grown at Waimea was decidedly higher in viscosity than starch from rootstocks grown at the central station in Honolulu. The fact that storage of the rootstocks, even for as short a time as 48 hours, reduced viscosity, showed that delays in the milling process should be avoided.

PRESERVATION OF HAWAIIAN FRUITS

The chemical division continued to work in cooperation with the small fruit preserving concerns on the different islands. One of the problems of the small producer is how to secure a steady supply of fruit throughout the year without having to maintain an expensive

reserve of glassware and finished jelly. The uncertainty of the system with respect to guavas led to a study of the practicability on a factory scale of storing the extracted juice in 1 and 5 gallon containers. No difficulty was experienced in preserving the juice, and preservation is expected to be less expensive than buying the fresh fruit the year around, due to lower prices prevailing during the culmination of the guava season.

COMPOSITION OF HAWAIIAN-GROWN VEGETABLES

Analysis was completed of the second crop of vegetables grown on the mainland (Arlington, Va.), and in Hawaii (Mokuleia, windward Oahu, and Honolulu). Comparison of the results of the analyses of the first and second crops showed only few consistent variations which can be attributed to differences in climate or soil. However, results of the experiment, together with the analyses of a series of some 60 fresh vegetables which were grown in Hawaii, prove that locally grown vegetables compare favorably in their mineral constituents with similar varieties grown on the mainland.

REPORT OF HALEAKALA SUBSTATION AND DEMONSTRATION FARM

By H. F. Willey

At the Haleakala substation and demonstration farm 75 rods of new fence were constructed and 70 rods of old fence rebuilt. All line and cross fences were maintained in good condition. Clearing of the gulch land for pasture was continued, although greatly handicapped by the aggressiveness of the native shrubby vegetation. About four acres of pasture land was put under cultivation as a part of a general rotation scheme. Some 173 varieties of 81 different species of crops were under test to learn their adaptability to local conditions, including pigeon peas, edible, canna, dry-land taro, field corn, sweet corn, pop corn, forage and pasture grasses, and numerous kinds of vegetables and fruits. Distributions were made of over 5,000 rootstocks of edible canna, 450 strawberry plants, 6,000 cuttings of sweet potatoes, and 10,000 cuttings of Uba cane. In addition to 20,000 cuttings of Merker grass and Napier grass, nineteen 1½-ton truck loads of these cuttings were distributed to interested persons desiring to make plantings on a large scale. The farm now supports 1 registered Holstein bull for community service, 3 cows, 2 heifers, 4 calves, 5 hogs, 2 mules, 1 saddle pony, 80 laying hens, and 75 young chickens. One of the Holstein cows gave 308 pounds of milk in three days. (Fig. 4.) Her bull calf is being reserved for breeding.

The superintendent assisted with the boys' and girls' club work, organized eight home and school-garden clubs, and obtained a total of 150 enrollments. Of these, 139 completed their work. He visited each of the 139 gardens twice each month during the school year, traveled 3,225 miles in connection with this part of extension work, prepared special exhibits for both the county and Territorial fairs, and assisted in arousing interest in the fairs and in judging the

exhibits. The superintendent also served as committeeman in connection with the Maui County Chamber of Commerce in the interest of all lines of agricultural extension. He assisted not only in marketing farm products, but also in obtaining the best seed and other planting material of crops desired by the various homesteaders. He made a trip to the island of Molokai and spent several days among the homesteaders who are operating under the Hawaiian Homes Commission.

For the first time in the history of the experimental work of the station, a severe hailstorm occurred and considerably damaged the growing crops. In addition to the hail, which was accompanied by a high wind, 2.3 inches of rain fell in the 30 minutes the storm lasted. The hail drifted in places to a depth of 18 inches and re-

FIG. 4.—Holstein cow with record of over 100 pounds of milk per day for three days, Haleakala substation

mained unmelted throughout the day, although the thermometer recorded a maximum temperature of 64° F. The elevation of the station is 2,100 feet.

REPORT OF EXTENSION AND DEMONSTRATION WORK ON THE ISLAND OF HAWAII

By R. A. GOFF

VISITS TO HOMESTEADERS

The extension agent made trips as often and as regularly as possible to the various districts of the island for the purpose of assisting homesteaders and others who are interested in the culture of diversified crops. He made recommendations regarding the kind of rations and crops to be fed livestock, gave advice on poultry culling, suggested remedies for the cure of certain poultry diseases, prepared plans for livestock buildings, gave demonstrations of the proper methods of spraying trees, outlined methods of fruit-tree planting in orchards and vegetable gardening, and otherwise materially assisted in solving farm problems.

EDIBLE CANNA

Waimea, although an ideal locality for the production of certain crops, is not adapted to the pineapple and sugar-cane crops upon which the economic prosperity of the Territory now depends. The district has a windy, moist climate, lies 2,600 feet above sea level and just below the frost line in winter, and is capable of producing from 30 to 40 tons of edible canna per acre in 15 to 18 months. Thousands of acres of land in Waimea are now devoted wholly to grazing. These should be put under cultivation with edible canna to form the basis of a starch-producing industry. The homesteaders are anxious for the local establishment of some industry which will enable them to market their produce readily. A small starch-extracting mill has been erected, and some 150 acres of land adjoining the homesteads have been planted with edible canna. The extension agent, working in cooperation with the chemical division, has made a number of field experiments dealing with the best time for applying fertilizers and for harvesting, tuber selection for planting, and the best method of planting in an effort to aid the industry in every possible way. Both homesteaders and members of the mill company are interested in the work under way. More than 12 acres of land are included in the experimental plats. Small areas have been planted in other districts in order that it may be learned what localities are best suited to canna production. The plats will be harvested this summer.

FARMERS' MEETINGS

Talks and demonstrations were given to interested groups of homesteaders on proper methods of pruning, budding, spraying, butter making, applying fertilizers, and growing and marketing crops.

MARKETS

Homesteaders in outlying districts have difficulty in finding a market for their corn, potatoes, fruit, and poultry products. Careful study was therefore made of the market requirements and to learn what time the produce would be ready for market. Arrangements were made in advance with local merchants to supply the local market and to cancel part of their orders with commission merchants on the coast. This willingness on the part of the resident dealers to buy home-grown products when the proper arrangements are made should encourage local producers to devote increased areas to their crops and to keep in closer touch with the local merchants than they now do. Demonstrations of grading and sorting fruit and potatoes were made with a view to obtaining better prices for the products.

DEMONSTRATION PLATS

Small plantings of pasture grasses and forage crops were maintained at the schools on both sides of the island. Stakes bearing the names of the crops were placed in each plat to aid the pupils in familiarizing themselves with the names and the habits of growth of crops which are best adapted to the several localities. The plats form a source of supply of seeds and cuttings for neighboring farmers.

KAMUELA-GRASS PLATS

Plantings of range grasses and forage crops occupying approximately a quarter-acre plat were maintained on an area of land formerly devoted to experimental work in cooperation with the Parker ranch. *Paspalum notatum*, *P. larranagai*, *Phalaris bulbosa*, *Exophorus unisetus*, *Panicum antidotale*, Rhodes grass, Napier grass, Merker grass, Peruvian winter grass, carpet grass, tall fescue, Uba cane, kudzu, sweet clover, and pigeon peas seem to be the best of the crops originally planted. Cuttings and seed of the plants were distributed to farmers in different parts of the island.

BOYS' AND GIRLS' CLUBS

Garden clubs, livestock clubs, canning clubs, bread-making clubs, sewing clubs, and home-improvement clubs were organized in the public schools on the island of Hawaii during the year. Club meetings were held, and assistance was given to local club leaders. Record books, Farmers' Bulletins of the United States Department of Agriculture, and other pamphlets of agricultural interest were distributed to members. Vegetables and corn seed also were distributed, and seed potatoes and livestock were obtained for members of the boys' clubs. Assistance was given in obtaining necessary material and equipment for members of the girls' clubs. The projects were inspected at the homes of members, where suggestions and encouragement were given to stimulate interest in the work. Club members exhibited their work at school fairs and at the county school fair.

SCHOOL AND HOME-GARDEN WORK

The extension agent acted as one of the judges in the home and school-garden contests in the Hamakua, North Hilo, and South Hilo districts. He frequently visited the schools and gave talks to the young gardeners concerning the adaptability of the different vegetable varieties to the various localities. He also gave advice regarding fertilizers and methods of planting and of combating plant diseases and pests. Similar work was carried on with individual gardeners, and visits were made to their homes, where garden problems were discussed and suggestions were given on record keeping.

HAWAII SCHOOL FAIR

The extension agent served on the committee of the agricultural section of the Hawaii school fair, which was held in Hilo in May, 1927. Vegetables from home and school gardens, livestock which was raised by members of the boys' clubs, and articles of clothing made by members of the girls' clubs were exhibited. In addition to aiding in making entries and arranging the displays, the extension agent assisted the members in bringing the exhibits to and from the fair. In connection with the vegetable exhibits he gave timely suggestions regarding the selection of seed of improved varieties and the proper methods of planting. He also assisted in conducting a quick-bread making contest which was participated in by teams from three of the girls' clubs. A trip to the forthcoming Territorial fair in Honolulu will be awarded the girls winning the contest.

ASSISTANCE IN BOY SCOUT ACTIVITIES

The extension agent again served as scout commissioner, as member of the traveling court of honor, and as special examiner for boys qualifying for agricultural merit badges.

PLANTING WINDBREAKS

Seedling trees suitable for windbreaks were distributed to farmers in the Kohala and Hamakua districts, where strong winds blow during a large part of the year. The trees are grown at the local nursery of the Board of Agriculture and Forestry and are taken by the extension agent to homesteaders living in remote parts of the island.

ASSISTANCE IN PLANTING FRUIT TREES

Seedlings on which were budded choice varieties of fruit, including the winter-bearing avocado, orange, lemon, and grapefruit, were distributed to growers in different parts of the island. Bud wood was given to agricultural instructors of the high schools, at two of which demonstrations in budding and grafting were conducted. Bud wood was also given to a number of homesteaders, and small seedling trees were budded in sections of the homesteads where they are to remain permanently. Seeds of the Solo papaya and suckers of the Chinese, Bluefields, and Hawaii cooking varieties of banana were also given to interested growers.

DISTRIBUTION OF SEED

Alfalfa and pigeon pea seed was distributed to livestock club members and also to schools for use in planting the summer gardens. Seed, cuttings, and roots from the Kamuela grass plats were distributed to livestock producers in all parts of the island. Waimea corn, imported Boone County White corn, and Hamakua Hybrid seed potatoes were taken to a number of schools and to homesteaders. Extra copies of seed catalogs were distributed on the trips, and assistance was given in selecting and purchasing seed of the varieties best adapted to the soils and climates of the different localities and to the needs of the individual farmers.

DISTRIBUTION OF LITERATURE

Newspapers and magazines containing interesting articles on agricultural subjects were loaned to various farmers, and bulletins published by the station and by the United States Department of Agriculture were distributed. Bulletins pertaining to agricultural topics were ordered through the station from the Department of Agriculture for use in the classrooms of teachers of agriculture at the junior and senior high schools.

REPORT OF BOYS' AND GIRLS' CLUB WORK

By Mabel Greene

STANDARD CLUBS

Interest increased in the work of the boys' and girls' 4–H standard clubs, and many new enrollments were secured on the islands of Oahu, Maui, Hawaii, and Kauai. New communities have become

interested on each of the islands except on Hawaii, where club activities were carried on with about the same number of enrollments as in 1926. Intensified programs were developed during the year, and additional rural communities in Oahu were reached.

The distribution of the boys' and girls' 4–H standard clubs of the islands is shown in Table 2.

TABLE 2.—*Enrollment of boys' and girls' clubs June 30, 1927*

Club	Distribution				Total
	Oahu	Maui	Hawaii	Kauai	
Canning	32	20	43	0	95
Clothing	312	122	182	44	660
Room improvement	1	0	6	0	7
Cooking	80	40	40	0	160
Garden	68	123	102	54	347
Pig	30	20	3	0	53
Poultry	42	0	14	0	56
Rabbit	0	5	18	0	23

Club activities were carried on in cooperation principally with the public schools and the International Institute of Honolulu, where organized 4–H club groups had definite programs of work. However, much interest in the demonstrational work of the clubs was shown by other institutions also. Five demonstrations in the proper methods of canning were given at the station to nearly 100 students of the department of home economics of the Territorial normal school. Demonstrations in cooking, preserving perishable food products, and sewing were given by the club leaders in five different communities in Honolulu in cooperation with the Columbus welfare work. The work covered a period of six months, one-half day each week being devoted to each project. Demonstrational work in making guavalets[2] and wearing apparel was conducted for the benefit of interested groups of Girl Reserves and members of the local Young Women's Christian Association.

FAIRS AND DEMONSTRATIONS

Many of the boys and girls of the 4–H standard clubs displayed exhibits and gave demonstrations at the Territorial fair. A large area in the agricultural building was allotted club exhibits, including garden crops, poultry, cooked products, canned fruits, jellies, and articles of clothing. Members of the fair commission cooperated in club activities by awarding ribbons and cash prizes to the young winners of the various contests, and this has been the means of fostering interest in the forthcoming Territorial fair. Members of the McKinley Poultry Club conducted a demonstration entitled "Poultry Feeds and Feeding," members of the Kaimuki Poultry Club, demonstrations entitled "Setting a Broody Hen" and "Setting Up an Incubator," and members of the Lincoln Poultry Boosters' team, a demonstration on "Culling for Egg Production." Considerable interest was aroused in contests in yeast-bread and quick-bread making, canning and cooking and serving vegetables, and "good buymanship."

[2] Confectionery made from the guava fruit.

A contest in quick-bread making was conducted at the Hilo school fair, held May 20 and May 21, 1927, with three teams of two 4–H club girls each from Honokaa, Honomu, and Laupahoehoe, Hawaii, participating. The Territorial fair commissioners have arranged to send the winning team, together with a boy from the Garden Club at Kauai and five girls and boys from Maui, to the Territorial fair which is to be held at Honolulu from August 29 to September 4, 1927. These boys and girls will act as representatives of their respective clubs and enable the 4–H clubs of Oahu to participate in the interisland contests in canning, gardening, cooking, poultry and pig raising, and clothes making. The contests stimulate interest in club work throughout the islands and are of value in encouraging the successful contestants to strive for entry in the larger meets, including the regional and national 4–H club camps.

FIG. 5.—Thrifty Boys' Garden Club. Beet growers

CLUB RECREATIONAL ACTIVITIES

Lantern slides from the United States Department of Agriculture on culling hens for egg production, judging hogs, and home and school gardens were shown at the school fair at Hilo, to over 1,000 boys and girls on Maui, and to members of the agricultural clubs on Oahu. Boys of the 4-H clubs and members of the Thrifty Boys' Garden Club (fig. 5) with pennants, caps, and banners appropriate to the occasion, were well represented in the boys' day parade, which was held May 7, 1927. The wearing of caps and achievement pins has attracted considerable attention and as a result their awarding has been given a place in the school programs. Demonstrations on the proper methods of canning and soap making were combined with good social programs by several of the girls' clubs working conjointly.

Members of the boys' and girls' 4-H clubs in Hawaii have been invited to participate in the activities at the regional Camp Plummer, near Portland, Oreg., from October 29 to November 4, 1927; a section of the fair grounds has been allotted to livestock club members at the Territorial fair to be held at Honolulu from August 29 to

September 5, 1927; and members of the canning clubs have been invited to participate in the exhibits of two glass-jar companies on the mainland this fall. The Pollyanna Club of Honolulu was liberally rewarded by one of the companies for its exhibit at Chicago in December, 1926. (Fig. 6.) This is the first time that clubs so distantly situated have been encouraged to participate in contests on the

FIG. 6.—Pollyanna Club members

mainland. Another glass-jar company is offering cash prizes to the four most successful contestants of the canning club in Hawaii this year, and is paying for an exhibit of Hawaiian fruits, vegetables, and fish which is to be prepared by Maisie Leong, a fourth-year club member. Such recognition of the merits of the local club work is encouraging both to club leaders and club members.

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HAWAII AGRICULTURAL EXPERIMENT STATION
HONOLULU, HAWAII

Under the supervision of the
UNITED STATES DEPARTMENT OF AGRICULTURE

Washington, D. C. June, 1929

REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION, 1928

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SUMMARY OF INVESTIGATIONS

By J. M. WESTGATE, *Director*

During the year covered by this report the work of the station was much the same as in previous years. Considerable attention was given to such crops as edible canna, coffee, and the Macadamia nut, all of which promise to become important agriculturally as the problems of production and marketing are solved. Attention was also given to the development of agricultural investigations dealing with tropical research.

Work of the horticultural division was devoted largely to the development of improved methods of budding and grafting tropical fruit and nut trees and to determining their cultural requirements. New varieties of various species were introduced and improved strains were developed largely by selective breeding. Comparative tests were made of these new and improved forms and the standard varieties. The horticulturist gave a number of demonstrations in budding and grafting for the benefit of students of the public schools and adults, and he served as chairman of the committee on fruit

exhibits at the two Territorial fairs which were held during the fiscal year. He also acted as one of the judges of the Star-Bulletin school-garden contests and distributed approximately 32,500 plants of new and improved kinds of tropical and subtropical fruits and nuts to applicants on the various islands and on the mainland.

Agronomic work was directed principally toward the development of root crops for human consumption, the production of feed for livestock and of starch, the development of the ginger industry, and the breeding of improved varieties of corn and lettuce. Experiments were continued with grasses which are promising especially as a feed for dairy cattle. Experiments were also made with various aquatic food plants and with other vegetable and food plants of oriental origin. Varietal studies were begun with sweet clover, pigeon peas, watermelons, and muskmelons. A manuscript describing a number of oriental vegetables grown in Hawaii was submitted for publication. Small lots of seed and other propagating material were given to numerous homesteaders to enable them to obtain a start of the various improved species and varieties of food and forage plants. The agronomist served as chairman of the poultry committee of both the sixth annual Territorial fair, held from August 29 to September 5, 1927, and of the seventh annual Territorial fair, held from April 30 to May 5, 1928. He continued to assist local poultrymen in the numerous problems connected with the industry.

The work of the chemical division dealt principally with the solution of problems arising in connection with the development of the edible-canna starch industry. Cultural, variety, and milling tests and studies to learn the relative effect of different field treatments and methods of harvesting on the properties of the resulting starch were made. Studies were begun dealing with the physical properties of tropical soils of volcanic origin, particularly with respect to the nature and properties of their colloids. Analyses of 56 Orient-grown vegetables in Hawaii were made, and the results submitted for publication in a bulletin in cooperation with the agronomy division.

The extension agent for the island of Hawaii again assisted individual small farmers by giving them information concerning production and marketing problems and also by endeavoring to develop new crop industries and to extend the culture and yields of minor established crops, including coffee. He also materially assisted with the boys' and girls' club work and served as a judge in the home and school garden contests and of the exhibits at the various school and Territorial fairs. During the year he traveled approximately 9,000 miles by automobile and 400 miles by boat in the interest of farmers living in different parts of the island.

Activities in the boys' and girls' 4–H clubs, including food-preservation clubs, bread-making clubs, cooking clubs, clothing clubs, garden clubs, pig clubs, poultry clubs, rabbit clubs, and horticultural clubs were carried out along the same lines as in previous years. A total of 1,209 children enrolled, and approximately 60 per cent of the members completed their projects. At the various local and Territorial fairs excellent facilities were provided for the display of club exhibits. These exhibits serve to acquaint the public with the value of such fields of endeavor.

At the Haleakala demonstration farm numerous tests were made to indicate the combination of crops and the kind of agricultural practices that are best adapted to sections comparable with the district in which the farm is located. During the year 170 varieties of 70 different kinds of crops or crop groups were under test and observation. Planting material of the most desirable varieties was furnished to farmers who desire to establish them on their farms. The superintendent assisted with the boys' and girls' 4-H club work and with the agricultural projects of the Maui County Chamber of Commerce, of which he is an active member.

REPORT OF THE HORTICULTURAL DIVISION

By W. T. Pope

The horticultural work for the fiscal year 1928 was of three general classes: (1) Plant introductions and distributions, and cultural requirements of tropical fruits and nuts; (2) investigations of the best methods of propagating tropical and subtropical fruit and nut trees; and (3) a study of varieties and habits of pollination of avocados, papayas, bananas, and tomatoes. The larger experiments dealt with the cultivation of the mango, avocado, Macadamia nut, date, breadfruit, papaya, and coffee, which are small industries or give promise of becoming such.

MANGOES

In the work with mangoes, studies were made of vegetative methods of propagating the tree, its cultural requirements, and the varieties found growing in the Territory. The problem of vegetative propagation is of considerable concern to anyone contemplating the establishment of commercial orchards.

Grafting experiments with mango nursery stock were continued not only to verify the results of the methods formerly tried, but also to increase the stock of propagating material of certain new varieties. Several forms of grafting were tried, including wedge grafts, whip grafts, and side-tongue grafts, each of which gave a reasonable amount of success. The side-tongue method, however, gave the largest percentage of successful grafts, as was the case during the two previous seasons. (Fig. 1.)

Experiments to learn the cultural requirements of the tree have been carried on at the central station, in one commercial orchard, and also in a number of privately owned gardens in various parts of the Territory. The two small mango orchards at the central station have been of value for furnishing considerable data on the cultural requirements of the tree and for making varietal studies, and also have been a source of good propagating material. The older orchard was set largely about 19 years ago and contains 68 trees representing 21 varieties. These were propagated in the early vegetative mango experiments and consisted of inarches and buds. The young mango orchard occupies about two-thirds of an acre plat and contains 43 trees, representing mostly grafted trees of varieties selected for certain qualities of fruit, such as resistance to fruit-fly attacks. This orchard is now in its fourth year and has displayed some fine examples of both the habits of growth and early produc-

tiveness of certain mango varieties. (Fig. 2.) Both orchards were cultivated during the year, and for a period the older orchard contained a cover crop of cowpeas. As a precautionary measure against the attacks of mango blight (*Glœosporium mangiferæ*), the trees of both orchards were sprayed with Bordeaux mixture twice during the two weeks previous to the opening of the blossoms. The season was very favorable for the development of the fruit, the rainy season closing just before the blossoms appeared and being followed by warm weather and trade-wind breezes. The mango crop throughout the Territory is very large this season, and the fruit is of good quality.

FIGURE 1.—Three forms of graft unions employed successfully in grafting the mango and the avocado at the station

The varietal studies included not only varieties that were introduced or developed by the station, but also those that have been brought to the attention of the station from all parts of the Territory. The characters for determining desirability are flavor, texture, color, and size of fruit, general marketing qualities, yield, and particularly resistance to the attacks of insect pests and fungus diseases. During the year a manuscript on mango culture in Hawaii was submitted for publication. Among the new varieties obtained during the year were the Whelan (station accession No. 5281), Ono (accession No. 5322), McDougal (accession No. 5280), Ludwig (accession No. 5298), and Bishop (accession No. 5247). The latter, as a small inarched tree, was introduced from Tahiti by G. P. Wilder. It has just fruited and has proved to be of very high quality. (Fig. 3.)

AVOCADOS

The development of improved methods of vegetative propagation of good varieties is the most important problem of avocado growers in Hawaii. Very excellent varieties have been developed, and new ones have been brought into the Territory, but as yet local markets rarely have any of the choice fruits for sale. During the year ex-

periments in grafting were given considerable attention. The side-tongue method of grafting 8-month-old seedlings gave about 48 per cent of successful grafts. The method of wedge grafting very young seedlings, ranging from 40 to 60 days old, was fairly satisfactory, but this season it proved difficult to obtain the young scion wood of good varieties at the time the young seedlings were ready for grafting. The means now employed to increase good varieties more rapidly is

FIGURE 2.—Lewis mango, 4½ years old, maturing 184 fruits. Hawaii station orchard

through a limited number of carefully located cooperative orchard projects. The station, as its part in the work, furnishes enough grafted trees to set an acre of land or fraction thereof, and supervises the culture; the cooperating orchardist furnishes the land, the implements, and the labor. The only compensation exacted by the station is the privilege of entering the orchard at any time for observation and study and of removing a reasonable amount of propagating material in season as may be desired.

The station orchard, containing mostly Guatemalan varieties, is located in the Tantalus substation on Mount Tantalus, where the elevation is about 1,000 feet. The past winter months were rainy,

FIGURE 3.—Bishop mango. Introduced into Hawaii from Papeete, Tahiti, December 16, 1926, by G. P. Wilder. Photographed June 15, 1928

and the spring was warm and otherwise favorable for natural growth and blossom development. Some time was given to pollination study. Under favorable conditions the fruit sets uniformly on practically

all the trees. Trees of certain varieties which have the reputation of being light yielders are still carrying a good crop of young fruits. Varietal studies were in progress during the year.

MACADAMIA NUT

A study of the variations of the Macadamia nut tree was made during the year. Considerable range of differences was noted in the fruit, foliage, and habits of growth of the seedling trees. What is known in some countries as the "common Queensland nut" (*Macadamia ternifolia*) is commonly found in this Territory. Normally the tree is tall, with upright branches and dark-green foliage. The leaves are often a foot long and arranged in whorls of three or four at the nodes. The leaf blades are without petioles, and the margins are wavy and serrated with prickles. The nuts are usually borne in clusters of 12 or more on a single axis. The surface of the hard shell varies from undulating to bumpy. Another type, known botanically as *M. ternifolia* var. *integrifolia*, is smaller and of more spreading habit, with leaves in clusters of three at the nodes, each having a one-half-inch petiole. The blades are spatulate, rarely more than 6 inches long, and the margins are without prickles or nearly so. Most of the flowers of each panicle fall away, leaving only one to three nuts to grow to maturity. (Fig. 4.)

In the groves studied there are many variations ranging between the above-mentioned types. Occasionally a tree will be found bearing both spiny-edged and smooth-edged leaves; some trees will produce oblong nuts with a deeply wrinkled husk and apex that is considerably extended. Occasionally a tree is found bearing two nuts in one husk, each nut having a hemispherical shape. Trees have been found with all the nuts of this undesirable shape. Another unsatisfactory habit not uncommonly found is the failure of trees to fruit at all. Variation in the quality of the nuts is also a common occurrence. These differences are not unlike those of seedlings of many other kinds of fruit and nut trees. Vegetative methods of propagation will have to be practiced before Macadamia nut culture can be expected to become an industry of any considerable consequence.

This year a number of propagating experiments were in progress. Trials were made with both seeds and vegetative methods. From results with the former it is concluded that seedlings may be easily produced by planting selected fresh seeds immediately following full maturity. At the station a propagating bed of coral sand about a foot deep has proved to be very satisfactory. Nuts which are planted 4 inches deep and kept moist usually germinate and produce shoots with active foliage in about 30 days. Very shortly after this the seedlings may be transplanted to gallon tin containers or 8-inch pots. Vegetative methods of propagating the Macadamia nut tree have proved to be more difficult. A number of methods were employed. Branch and root cuttings of different forms were tried in different mediums without satisfactory results; air layering, inarching, and various other forms of grafting proved to be more hopeful, especially side-tongue grafting and whip grafting. These grafts were successful when seedling stocks nearly a year old, growing in gallon tin containers, were used. Side-tongue grafts and whip grafts when well made and the union, including the entire scion, coated with

paraffin, succeeded with little difficulty. It is believed that this method, with possibly some improvement, may be utilized in standardizing a good variety which will mean much toward developing the Macadamia industry in Hawaii.

FIGURE 4.—*Macadamia ternifolio* var. *integrifolia*. Foliage, flower, and fruit, showing the characters of the variety

DATES

Investigations to learn the possibilities of developing a commercial date industry in Hawaii were made during the year. There is considerable local interest in date growing. Choice dates are pro-

duced in various parts of the Territory. Unusually fine specimens of the fruit were exhibited at the Territorial fair, which was held from August 29 to September 5, 1927. During the fall several seedling trees of the Deglet Noor variety were in bearing at the Girls' Industrial School, Honolulu. Date seeds of 10 varieties introduced last year produced 425 seedling trees, which are being placed in cooperative experiments with carefully selected growers. One lot of 100 trees, 10 of each variety, was located with L. Faye, of Kekaha, Kauai. These trees were delivered in December, 1927. This grove is in an unusually warm locality on low, silt-formed soil approximately one-eighth mile from the sea. The land is high enough for good underdrainage and is watered by a good irrigation system in which mountain water is used.

In another cooperative experiment which was arranged with E. P. Fogarty, of Waianae, Oahu, 80 seedlings, representing 5 varieties, were planted on low land 1 mile from the sea. It is hoped to arrange for two other cooperative experiments in other parts of the Territory where conditions are believed to be favorable for date growing. Date palms, particularly young seedlings, have been attacked by a fungus (*Graphiola phœnicis*) which develops on the foliage in numerous pustules having the appearance of yellowish-white crumbs. The fungus is common on the date palms of many countries and is not considered to be serious in Hawaii.

BREADFRUIT

The breadfruit experimental work included studies to determine the best methods of propagating the tree and studies of the introduced varieties. During the year a number of root cuttings of varieties from the South Sea Islands were collected by G. P. Wilder and sent to the station for trial in a cooperative experiment. The material was assembled at Papeete, Tahiti, from different islands in that part of the Pacific and made the long journey to Honolulu via San Francisco. In some cases the roots were out of soil for a period of 38 days. Some, no doubt, were collected at a season when the cuttings could not withstand shipment. Consequently the percentage of cuttings that sprouted was very small. Including the introductions of previous years, about 50 South Sea Islands' varieties have been received to date for trial. Owing to difficulties experienced in rooting the cuttings, less than half of the varieties are established. Some of the trees of the earlier introductions are now large enough to furnish cuttings from the branches, and a trial of rooting these has given about 26 per cent of successful results. The results of the early experiments of propagating root cuttings of seedless breadfruit of the Hawaiian variety, conducted in 1922–23 and in 1923–24, indicated that these cuttings are the most successful when they are collected during the dormant period of the tree, preferably just before or at the beginning of the revival of annual growth. The dormant period usually continues for two or three months each year, beginning immediately after ripening of the crop. The root cuttings must be handled with care and not allowed to become dry at any time. They can not be suitably packed to withstand long distance shipments, and quarantine regulations do not permit them

to be brought into the Territory in soil. Seedless breadfruit trees which were developed from root cuttings collected in Tonga, Samoa, and Tahiti four and five years ago are now growing in various places in the Territory. Most of these trees have made remarkable growth

FIGURE 5.—Tutou seedless breadfruit tree, 3 years old. Introduced as a root cutting from Tahiti and propagated at the station. Tree growing at Mokuleia, Oahu

and are a source of material for varietal study. Several of the trees that were set out at Mokuleia, Oahu, are beginning to fruit. (Fig. 5.) Several trees of the Maopo variety are growing at the station. This variety is excellent for its fruit and for ornamental purposes. (Fig. 6.)

PAPAYAS

A total of 404 papaya trees occupying a little less than two-thirds of an acre plat is under trial at the station. Fields C–II and C–III contain 214 trees, set in 1926, representing six types according to nature of fruit or place whence the seeds were obtained. The stami-

FIGURE 6.—Maopo breadfruit tree from Tonga Islands. Introduced as a root cutting and now growing at the station

nate-flowered kinds constitute less than 10 per cent among the dicœcious types, and the sterile or nearly sterile trees constitute about 15 per cent among the moncœcious types.[3] The two rows of Solo papaya trees have not proved to be satisfactory. The fruit has not

[3] Sterility among the unsettled sex forms of different kinds usually appearing in the moncœcious types is described in the following publication: HIGGINS, J. E., and HOLT, V. S. THE PAPAYA IN HAWAII. Hawaii Agr. Expt. Sta. Bul. 32, 44 p., illus. 1914.

been uniform and has in some instances been of entirely different shape from that usually produced by this strain of papaya.

The small grove in field A–III containing 190 trees representing a number of kinds was set in December, 1927, for a sex test. Of the monœcious, long-fruited kinds, the planting contains 15 trees of station accession No. 5313 from Africa, 13 trees of No. 5309, 19 trees of No. 5314, 19 trees of No. 5312, and 12 trees of No. 5311; and of the diœcious, round-fruited kinds, 15 trees of No. 5306, 14 trees of No. 5315, 11 trees of No. 5316, 14 trees of No. 5308 (seed from apex of fruit), 11 trees of No. 5206 from Panama, 6 trees of No. 5208 from Singapore, 4 trees of No. 5289 from Malaya, 14 trees of No. 5307, 7 trees of No. 5200, designated "he's," 6 trees of No. 5201, designated "she's"; and of the Solo variety, 10 trees.

During May and June, 1928, these trees began to blossom. Nearly all the monœcious type were in blossom by June 30. They show about the usual sex variations found in a grove of this kind. In the diœcious type the staminate trees number a little more than 50 per cent. Station accessions Nos. 5200 and 5201, received by mail from Tahiti, Society Islands, last year, were germinated in the fall and the young seedlings transplanted to the field in December, 1927. The lot of 20 seeds of each variety had been selected by a man from Anam who claimed that he could determine the sex of the future trees by the appearance of the individual seeds. He separated the seeds into two groups, which he designated as "he's" and "she's." From the "he's" seven trees were grown, six of which are staminate or males; one has not yet blossomed. From the "she's" six trees were grown, four of which are males and two females.

COFFEE

The coffee investigations were devoted, in part, to field studies of the present methods of culture, soil characters, and handling requirements. The main portion of the work was carried on in the coffee-growing section of Kona, Hawaii, during August and January of the present fiscal year. Coffee raising is carried on mainly by private growers, each of whom cultivates a small grove and handles his own crop in the manner that he deems best. Little attempt is made to learn what is being done to improve the crop in other coffee-growing countries. The work with the crop includes picking the ripe berries, a complicated process of pulping, and a system of sun drying the seeds for a considerable period without interference from dampness. Soil characters also are of importance. The coffee district of the island of Hawaii lies on the slopes of two great volcanic mountains. These slopes are composed of lava flows varying in age from the ancient to the more recent. The flows also vary greatly in composition and nature of formation, but in general are classed locally as "a-a" flows and "pahoehoe" flows. The former consists of broken up, clinkerlike lava which, when there is abundant rain, rapidly decomposes into a deep soil that is favorable for coffee-tree growth; the pahoehoe flows form great rolls of hardened lava which slowly disintegrates and often carries a shallow surface soil that is unsuitable for coffee culture.

About 800 trees of *Coffea arabica* have been grown at the station. This nursery stock is 18 months old and ready for budding and grafting experiments and for cooperative cultural tests. It is planned to test the effect of several different kinds of fertilizers on yield of coffee and to use the field for experiments in improving Hawaii coffee through hybridization with other species. Budding and grafting experiments with coffee were begun. Through the Office of Foreign Plant Introduction, United States Department of Agriculture, about 70 coffee seedlings of three species, *Coffea arabica*, *C. excelsa*, and *C. robusta*, were recently obtained from another part of the world.

MISCELLANEOUS NOTES

Minor work was done with figs, tomatoes, strawberries, mountain apples, annonas, pecans, chestnuts, bananas, watermelons, grapes, guavas, citrus, litchi, cashew, pomegranates, roselle, sapodillas, star apples, rubber, and fiber plants. Plants of several varieties of grapes were added to those already under test. A number of seedlings of cherimoya and also of the litchi were successfully grafted. The production of both the cherimoya and the litchi offer possibilities of becoming small industries. The mountain apple which responds to good culture is very much in demand locally. The citrus orchard received the usual amount of care and has proved to be a convenient source of graft wood.

Approximately 88 new accessions of plants and propagating material were received. Among the more important additions were grape plants of the varieties Isabella Regia, Gros Guillaume, and Olivette Blanche from California; *Garcinia berthami* from the Bureau of Agriculture of Manila, P. I.; seeds of cacao from the Division of Agriculture, Apia, Samoa; a new variety of mango, and propagating material of a number of varieties of seedless breadfruit from Papeete, Tahiti, Society Islands.

The horticultural department responded to numerous requests for horticultural information from growers and visitors to the station. Exhibits were prepared for two Territorial fairs, held from August 29 to September 5, 1927, and from April 30 to May 5, 1928. Twenty-one horticultural demonstrations were given during the year and 60 hours devoted to work in the classroom at the summer session of the University of Hawaii, in July, 1927. The horticulturist also acted as judge in one school-garden contest, made three trips to each of the 22 public-school gardens on Oahu in the spring of 1928, distributed numerous fruit plants and propagating material from the station nursery and orchards, and twice inspected six cooperative experiments during the year.

REPORT OF THE AGRONOMY DIVISION

By H. L. Chung

GINGER

In October, 1927, a survey was made of the ginger situation on the island of Maui to determine the area now devoted to the crop and the possibilities of extending it. The area was found not to exceed 2 acres. Private gardeners have small patches of ginger, none of

which exceeds 2,500 square feet in area. Only a sufficient amount of ginger is grown to meet demands on Maui. The Maui gardeners are willing to extend the area in ginger upon being guaranteed from Honolulu or elsewhere that the surplus will be absorbed. A cultural and fertilizer test was made at the station field N with two different varieties of ginger. Enough propagating material has been obtained to permit enlargement of the ginger project during the coming year. In a study of the quantity of fresh ginger annually imported into the United States of America, a total of 4,951,657 pounds of ginger was found to be recorded for 1926. Of this quantity, New York received 4,633,120 pounds and California 318,537 pounds.

SWEET POTATOES

Approximately 146 sweet-potato hybrids, chance seedlings, and standard varieties were tested during the year to determine their relative merits. These were planted in short cycles of three months each as a means of checking the activities of the sweet-potato weevil. Of the varieties tested, 1 produced at the rate of over 46,000 pounds

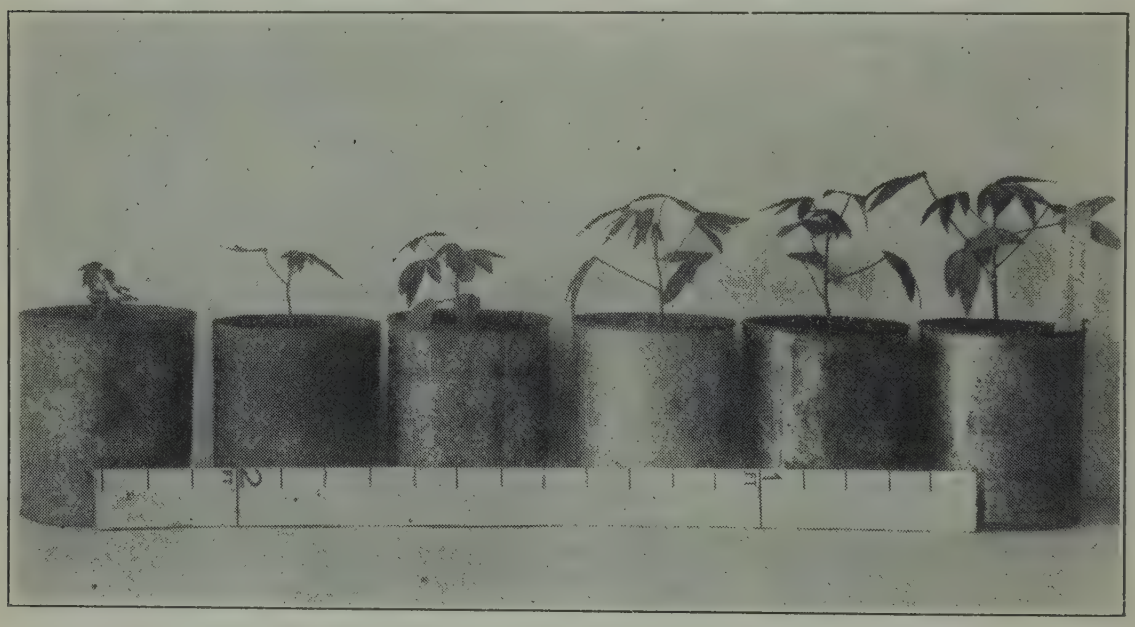

FIGURE 7.—Cassava seedlings 67 days old

of tubers per acre, based on the yield of 8 hills, 5 produced over 35,000 pounds, 7 over 30,000 pounds, 13 over 25,000 pounds, 29 over 20,000 pounds, and 23 over 15,000 pounds. These yields were obtained from a comparatively few hills of each lot (6 to 30), which, however, were grown 2 feet apart in 3-foot rows. The rows were grouped to simulate field conditions. From these productive varieties propagating material has been made available to local sweet-potato growers desiring to grow heavy-yielding varieties.

CASSAVA

A large number of the cassava varieties flowered and seeded freely. From the matured seeds a number of seedlings were obtained for use in comparative tests. (Fig. 7.)

TARO

Seventeen wet-land and twelve dry-land varieties of taro were grown. The former group, containing many Hawaiian varieties, was

cultivated chiefly to determine yields and to learn, if possible, their true native names. In the dry-land group a study was made to determine the best yielding varieties for dry-land conditions and to improve their productive qualities by selective breeding.

In connection with the wet-land variety culture, lime was applied to one of the plats to permit a preliminary study of the effect on taro rot.

CORN

During the early part of the fiscal year a study of the variation of the station hybrid sweet corn was made. Three distinct strains were obtained. Each was segregated according to the color of the silk. The selected ears of each strain were planted in order that their yielding qualities and their resistance to attacks by insect pests and diseases might be noted.

Further selection was made of the white and yellow Guam hybrids and the Cuban Red corn. Selected seed from the 1927 crop was planted in January to improve further these varieties by selective breeding.

RICE BORER

In February, 1928, the agronomist called the attention of the Territorial entomologists to the fact that certain local rice fields were infested with a rice borer (*Chilo simplex*). (Fig. 8.) This pest threatens to become a serious menace to the local rice industry unless its ravages are checked. At present (June 30, 1928) the pest is confined to leeward Oahu.

FORAGE GRASSES

The established plats of cultivated grasses were again maintained at the trial grounds. Seeds and cuttings from the area were distributed to ranchmen and to dairymen.

ALFALFA

A variety of alfalfa of apparently unknown origin was grown during the early part of February. The first cutting was made in May, 1928, after a growing period of 80 days. The alfalfa yielded at the rate of 23 tons of green forage per acre. The variety appears to be a very promising addition to the alfalfas already being grown.

SWEET CLOVER

A trial planting of 13 varieties or strains of sweet clovers was made in November, 1927. Of these, S. P. I. No. 27465 (Agr. No. 2092), a semierect variety, appears to be the outstanding one, and is closely followed by F. C. No. 03917 (Agr. No. 2083). These clovers were sent to the station for sectional cultural tests by A. J. Pieters of the Office of Forage Crops Investigations, United States Department of Agriculture.

PIGEON PEAS

Eight distinct varieties of pigeon peas were collected in India and sent to the station by F. G. Krauss, collaborator of the station. These were planted, and records have been kept of their growth and

yield. Among them was a variety which appeared to be an annual. It bloomed when about 12 inches high, produced a crop of seed, and died.

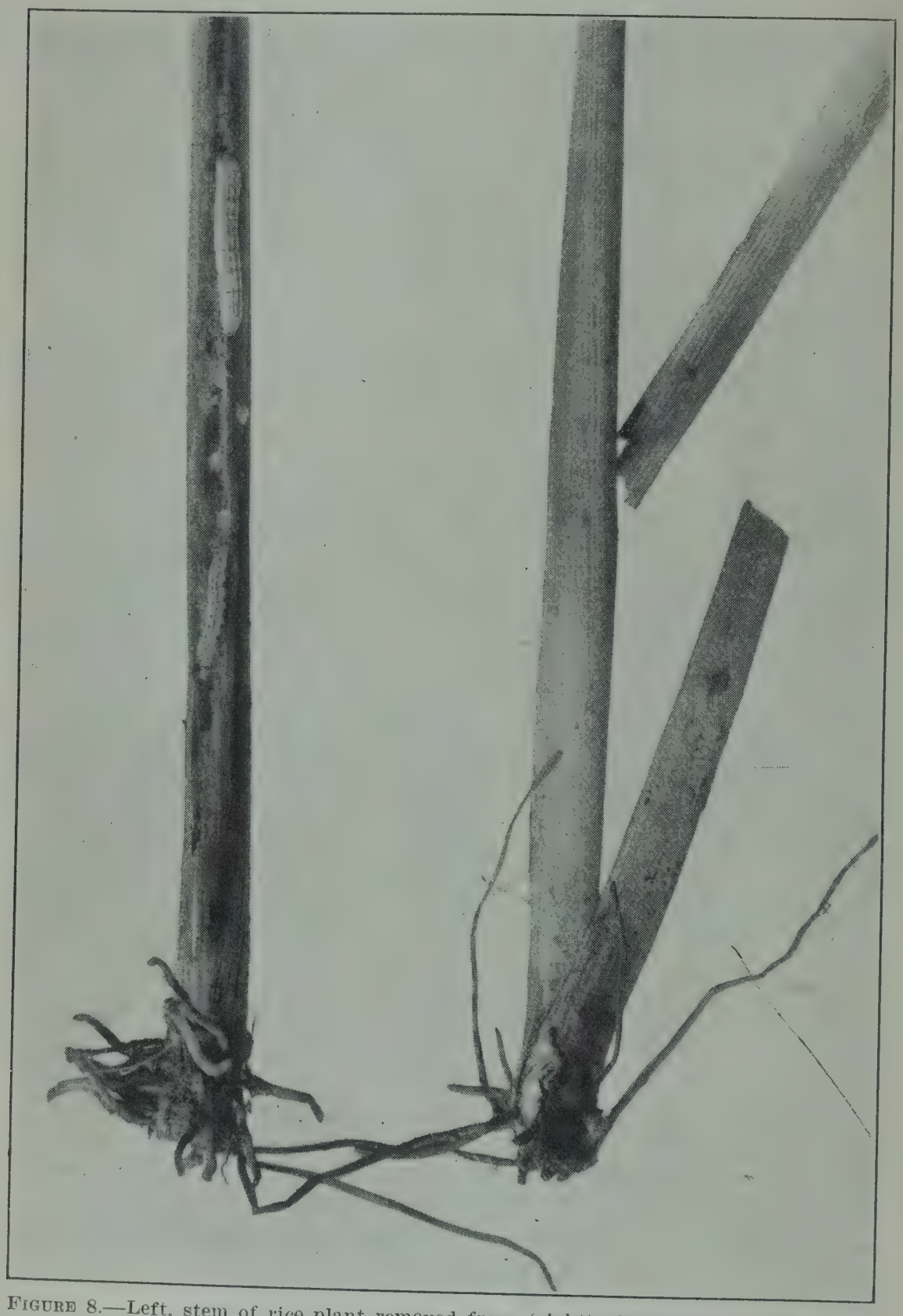

FIGURE 8.—Left, stem of rice plant removed from (right) sheath, showing the presence of the rice borer, *Chilo simplex*, and the nature of the damage done by it

BEANS

The Kentucky Wonder bean is considered the best pole variety for home and school gardens in Hawaii. Its prolificacy makes it the most popular local variety. Selective breeding of the Kentucky

Wonder bean has been under way at the station for the past three years. The object is to improve the general appearance of the pods and to increase further the productiveness by increasing the length

FIGURE 9.—Kentucky Wonder beans from selective breeding

of the pods. During the past year a single plant was noted to have produced pods 9 to 10 inches long. (Fig. 9.) The average length of the pods of the Kentucky Wonder bean is about 6 inches.

MELONS

The demand for information regarding the culture and relative merits of the various standard varieties of muskmelons and water-

melons has been almost constant from farmers interested in their culture. The agronomist secured seed of eight standard varieties of muskmelons and nine varieties of watermelons and distributed sample packets for cooperative variety tests to the different farmers who are interested in melon culture.

INSECT-REPELLING PLANTS

A trial planting was made of the insect-powder plant (*Pyrethrum roseum*) to learn its value in rotation with pineapples and the ability of the green manure when plowed under to act as a poison or repellent for nematodes. This plant was grown with difficulty on the heavy type of soil at the station, and a field test on one of the pineapple plantations is therefore being made.

LETTUCE BREEDING

An attempt is being made to develop lettuce plants which will head satisfactorily at the low altitudes in the Tropics. No positive results have thus far been obtained. Although over 1,000 hybrids were made from the heading varieties, only two crosses were found in the 1927–28 breeding work appearing to have the heading characteristics of the All Season and Mignonette varieties. The latter are standard varieties which have been found to be the best adapted to local conditions. Whether the heading qualities of the two hybrids are fixed or will fluctuate can not be definitely determined until further generations have been obtained. Possibly the increased vegetative vigor incident to the hybridizing may act as a deterrent to satisfactory heading. From observations made thus far, most of the hybrids show the characteristics of both parents except in the matter of heading.

POULTRY

The agronomist assisted in staging the poultry and pigeon shows at the sixth and seventh annual Territorial fairs. At the sixth fair, held August 29 to September 5, 1927, the poultry division exhibited both chickens and pigeons, and at the seventh fair, held April 30 to May 5, 1928, only pigeons. The 662 birds occupied two buildings. The agronomist also acted as a judge in the vegetable and field crops contest at the eleventh annual Maui County fair, and assisted in assembling the poultry and pigeon exhibits from Honolulu. In the latter part of the year he contributed a weekly article on poultry and pigeon topics to a local daily paper.

Judging from the keen interest now being taken by the local poultry fanciers in the industry, the standard of Hawaiian-bred poultry should be very high within a few years. This prediction is based on the interest continually manifested in the shipping of high-class hatching eggs direct from the mainland to the Territory. Now that it is possible to ship eggs from San Francisco to Hawaii in four and one-half days, hatching eggs 5 days old can be imported from San Francisco and 8 days old from the other cities along the Pacific coast via San Francisco. The agronomist advised intending importers of hatching eggs how to order and handle them. These eggs have shown percentages of hatchability ranging from 19 to 66.

REPORT OF THE CHEMICAL DIVISION

By J. C. Ripperton and C. Richter

EDIBLE CANNA INVESTIGATIONS

Investigations relating to the growth and culture of the edible canna and the properties and processes of the manufacture of its starches were continued.

NATURE OF THE GROWTH OF THE EDIBLE CANNA PLANT

A number of small experiments concerning the nature of the growth of the edible canna plant were completed.

By tagging of the newly developed stalks in each of a series of 40 hills the relationship of the number of stalks in the initial growth to the weight of the hill at harvest was determined. Except in subnormal hills, the initial number of stalks was found to have little relationship to the ultimate size of hill.

A large number of genealogizations were averaged. These averages showed that after the third generation there is always a large excess of buds over the number which is able to develop in a normal hill. The vigor of the initial stalk growth rather than the number of stalks is probably therefore the important factor in determining the ultimate size of the hill.

A series of hills was harvested at the end of six months and the relationship between the seed piece and weight of the hill determined. The size of the hill was found to decrease with the size of the seed piece below a certain minimum weight. Above this minimum there is no certain correlation.

A series of hills at Waimea, Hawaii, was harvested at monthly intervals and the number of rootstocks having developed and undeveloped stalks (spikes) determined. For over a 6-month period the total number of stalks remained nearly constant, but the spikes increased regularly. This bears out the theory that only such proportion of rootstocks develop stalks as is required to maintain the optimum leaf area required by the plant, the remaining spikes functioning simply as storage organs.

A series of adjacent hills was harvested from fields at the central station, Honolulu, and at Waimea, Hawaii. At Waimea variation in the total weight of the various hills appeared to be a function of the total number of rootstocks rather than of the average weight. There was no definite correlation with the station hills. With respect to the difference in the hills from the two localities, the number of rootstocks per hill was nearly the same, but the average size per rootstock, and hence the total weight, at Waimea was outstandingly greater.

A series of hills at Waimea, Hawaii, and at the central station, Honolulu, was visited at monthly intervals, and the new stalks were tagged for a period of 12 months. These values when plotted showed very marked difference between the two locations: At Waimea very definite cycles of stalk development were apparent, which did not appear at the station. At Waimea the number of spikes was large, whereas at the station there were practically none. These differences are explained by the fact that at Waimea the optimum stalk develop-

ment is reached after a certain period. At the station adverse climatic conditions prevent this optimum development; hence the stalk of each new rootstock developed as soon as the rootstalk was formed.

FIELD EXPERIMENTS

In experiments with edible canna carried on in cooperation with the extension agent on Hawaii, the crop was harvested in the station's experimental field at Waimea. Of especial import was the slowness of germination of seed planted in November as compared with that of the August plantings. If this is borne out in subsequent experiments, seasonal planting would be necessitated rather than a regular schedule of planting and harvesting throughout the year. First harvest and second planting were made of the hill-selection experiments. Individual records of 216 hills used in this selection are to be kept over a period of three to five harvests, when selection of outstanding hills will be made.

In addition to the hill-selection experiment, further work was undertaken to determine the possibilities of selection, based on such characters as largeness of individual rootstock and vigor within an otherwise dormant hill. The experiments on seasonal plantings and harvestings were repeated, because definite knowledge on these two points is of fundamental importance in the establishment of edible canna starch industry.

Four experiments were begun on Oahu in cooperation with a local pineapple company, to determine the value of edible canna as a green-manuring crop in pineapple culture. In two of these experiments, located at Kunia and at Waipio, the crop was dug because of its apparent susceptibility to nematodes. The other two plats, at Pupukea and at Kaneohe, show very little nematode infestation thus far.

MANUFACTURING PROCESS

The chemist and the extension agent for the island of Hawaii spent seven weeks investigating the defects of the milling process in a starch factory at Waimea. A number of reports concerning the defects and recommended changes in the process were submitted to the company. The following are among the more important conclusions drawn: Mechanical defects result largely from the use of too much makeshift machinery. Although there is as yet no modern edible-canna starch-mill machinery, certain of the standard machines used in the manufacture of potato and cassava starches are adapted to edible-canna starch manufacture and could be used for the purpose. The chief difficulty in the process is the removal of the fine soil particles from the extracted starch. This can not be done by levigation or by fluming, because of the rapid settling of canna starch. It must be accomplished either by screening the starch milk, or by freeing the rootstocks from soil before they are shredded, or by both methods. Screens and washing machines used in the manufacture of other tuber starches will probably have to be modified somewhat for edible canna, to give satisfactory results. It is recommended that one machine of each of certain specified types appearing to be adapted to the process be ordered and set up temporarily,

and the process worked out step by step by means of small trial runs, beginning with washing the rootstocks and progressing through the shredding, extracting, screening, refining, and drying stages. With the satisfactory adaptation of each machine orders could be placed for the whole mill. In connection with the refining screens, a revolving screen was constructed which apparently eliminated all the difficulties encountered in the shaking screens now used in the process.

METHOD OF DETERMINING THE PROPERTIES OF STARCHES

Further tests with the viscosity method of determining the "strength" of a starch showed that the utmost precision is required to secure concordant results. While closely agreeing results can be obtained for a period of days, a slight difference in the method of procedure in the same laboratory is sufficient to give another series of results. This method was therefore discarded in favor of a method which was developed to measure the swelling power of the starch. The latter method, an adaptation of one proposed by Harrison,[4] measures the volume of the granules of starch that has been previously cooked, poured into a cylinder containing distilled water, and allowed to settle. The swelling power of the starch is then expressed in terms of cubic centimeters of settled-starch mass per gram of oven-dry starch. This method is not only adapted to scientific investigations concerning the properties of starches, but is ideal for mill control since it requires simple, inexpensive apparatus and is simple in theory as well as in practice.

Investigation is now being made of the effect upon the swelling power of starch (1) of time and temperature of cooking, (2) of the various ions, (3) of nonelectrolytes, and (4) of hydrogen-ion concentration. Of special import is the relatively large effect of electrolytes in depressing the swelling power of edible-canna starch as compared with other starches. The addition of as little as 1 part per million of certain ions to a solution of the swollen granules of edible-canna starch causes a very appreciable shrinkage.

The effect on the swelling power of edible-canna starch of difference in climatic conditions and age of planting, storage of rootstocks and of wet starch, and variations in the milling procedure is being further studied.

STUDIES OF PHYSICAL PROPERTIES OF TROPICAL SOILS OF VOLCANIC ORIGIN

As a part of a general investigation of the physical properties of tropical soils of volcanic origin, work was begun on the soil colloids. Soil samples of typical uplands and beach agricultural lands and of unusual and extreme types have been collected. The apparatus has been assembled for dispersion, separation, and purification of the colloids. In connection with an investigation begun earlier, a number of soil samples from areas irrigated with brackish water have been included in the above-mentioned study to determine the specific effect of salt upon the soil colloids.

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[4] HARRISON, W. ON SOME PROPERTIES OF STARCH RELATING TO ITS STIFFENING POWER. Jour. Soc. Dyers and Colourists, 27 : 84–88, illus. 1911.

PRESERVATION OF HAWAIIAN FRUITS

In connection with the practice of canning guave juice for use by local fruit-preserving concerns when the fresh fruit is out of season, it was found that while the flavor, color, and clarity of the jelly from the canned juice was excellent, the pectin content deteriorated to such an extent as to necessitate the addition of pectin to produce a jelly. Deterioration in pectin does not occur when the juice is stored in 1 to 2 quart containers, but occurs in that stored in 1 to 10 gallon containers, due probably to the longer time the larger quantities of juice hold the heat. Notwithstanding the deterioration, storing of the extracted juice is recommended because the addition of pectin adds only a nominal cost as compared with the value of the finished jelly.

REPORT OF HALEAKALA SUBSTATION AND DEMONSTRATION FARM

By H. F. Willey

The Haleakala substation and demonstration farm continued its work of determining the kinds of crops and cultural practices that are best adapted to the section in which it is located. Propagating material of the most desirable varieties was distributed to farmers throughout the island of Maui. Distributions were made of 1,600 pounds of edible-canna tubers, 600 strawberry plants, 6,500 cuttings of sweet potatoes, 1,000 cuttings of Uba cane, and 21 truck loads of Napier grass and Merker grass cuttings for planting on a large scale. Distributions in lesser quantities were made of pigeon peas, field and garden beans, tomato seed, pop corn, field corn, cassava, taro, vetch, rhubarb, and asparagus. Some 178 varieties of 70 species of crops were tested, including 23 varieties of taro, 18 varieties of fruit trees, 15 varieties of cultivated grasses, 12 varieties of sweet potatoes, 12 varieties of beans, 10 varieties of windbreak trees, 12 varieties of beans, and a smaller number of varieties of pigeon pea, purple vetch, sorghum, *Meibomia rensoni* (the barajillo of Salvador), alfilaria, Australian saltbush, cassava, edible canna, radish, carrot, beet, lettuce, onion, squash, pumpkin, cucumber, turnip, pepper, tomato, pea, kohl-rabi, parsley, sage, asparagus, rhubarb, roselle, strawberry, pineapple, grape, blackberry including Logan, raspberry, dewberry, gooseberry, currant, peanut, field corn, pop corn, sweet corn, oats, barley, flax, wheat, rye, clover, watermelon, muskmelon, and field beans.

The superintendent devoted considerable of his time to the boys' and girls' 4-H club work and also assisted with the school-garden contests and the exhibits at the county and Territorial fairs. Eighty-one of the 4-H club members on Maui entered the Honolulu Star-Bulletin home-garden contest, and won nearly all the prizes. The superintendent also assisted the farmers in solving problems of production and marketing, served as a committeeman of the Maui Chamber of Commerce, and acted as agricultural representative and committeeman on public lands.

REPORT OF EXTENSION AND DEMONSTRATION WORK ON THE ISLAND OF HAWAII

By R. A. Goff

The extension agent made trips as often and as regularly as possible to farmers and ranchmen in all parts of the island. He also gave advice regarding poultry and hog raising, dairying, market gardening, purchasing seed, combating crop pests and diseases, and the growing of improved grasses for cattle ranges. He prepared plans for livestock buildings and outlined methods of fruit-tree planting in orchards, and gave encouragement to the school and home-garden work carried on by pupils of the public schools.

EDIBLE CANNA

The manufacture of starch on a commercial scale from edible canna is a comparatively new industry. Problems are therefore constantly arising in connection with field practices, crop production, and milling. Considerable time was devoted to the crop in the Waimea district where there are nearly 100 homesteaders who are interested in the establishment of a starch industry, and it is possible to utilize some of the thousands of acres of land now devoted to grazing, for canna production. Field experiments dealing with tuber selection for planting, seasonal plantings to determine the effect on yield, the use of fertilizers, and a study of the canna-plant diseases, which have been in progress for several years, were continued. New machinery was installed in the hope of improving local manufacturing methods in the starch factory.

FARMERS' MEETINGS

Talks were given to interested groups of farmers in the homesteading districts on miscellaneous agricultural topics including feed production, marketing crops, poultry raising, fruit orchards, and vegetable gardens. Spraying demonstrations were given on methods of controlling weeds and garden and fruit-tree pests.

BOYS' AND GIRLS' CLUBS

Boys' and girls' club activities, including livestock clubs, gardening clubs, cooking clubs, and sewing clubs, were organized or continued in three districts of the island. Regular and special club meetings were held, at which plans were formulated, suggestions given, and record books and Farmers' Bulletins of the United States Department of Agriculture, distributed. Assistance was given in obtaining poultry and pig breeding stock and arranging payments for the same. Seed was distributed to club members wishing to plant crops to furnish feed for their livestock. Materials for the sewing clubs were secured and distributed. Exhibits of livestock and completed project work were made at a local fair as well as at the Territorial fair in Honolulu. The club delegates cooperated in demonstrational work and judging club exhibits at the Territorial fair.

MARKETING

Assistance was given to farmers in marketing their produce in Hilo and Honolulu by making arrangements with merchants for the handling of such commodities as fruit, including avocados and oranges,

poultry products, and corn and potatoes. Samples of improved packing boxes and containers for shipping fruit and vegetables were shown. Demonstrations of grading and properly packing for shipment were given, with a view to obtaining better prices for the producer.

DEMONSTRATION PLATS

Small plantings of pasture grasses and forage crops were maintained at schools in different parts of the island. The names of the different crops were placed on stakes in each plat to aid the pupils of the school and visiting parents in familiarizing themselves with the names of the crops that are best adapted to the several localities. Seed and cuttings from the plats were distributed to those wanting them.

KAMUELA GRASS PLATS

Plantings of 5 pasture grasses and 10 soiling crops are being maintained by the Parker ranch in the cooperative experimental plats previously planted by the extension agent in Kamuela. Seeds, cuttings, and roots are taken from Kamuela and distributed to ranchmen, dairymen, and homesteaders and to schools in other parts of the island. The distributions included *Exophorus unisetus*, *Panicum antidotale*, *Paspalum larranagai*, *P. notatum*, *Phalaris bulbosa*, carpet grass, Merker grass, Napier grass, Peruvian winter grass, Rhodes grass, tall fescue, Uba cane, pigeon peas, and sweet clover.

SCHOOL AND HOME GARDEN WORK

The extension agent acted as one of the judges in the school-garden contests on the east side of the island. He visited the schools to give talks concerning methods of combating garden pests, and of planting seed, and the proper use of fertilizers. He also assisted the young people in purchasing seed, and gave a talk on seed selection and storage, marketing, and the use of cover crops. He visited the projects of the young gardeners and gave suggestions on methods of improving both gardens and record keeping. He also visited and acted as a judge of the home projects of the students working under the Smith-Hughes vocational education act in the junior and senior high schools in the Kona, Hamakua, North Hilo, and South Hilo districts. These projects are devoted to sugar-cane and coffee culture and to poultry, pig, and dairy-cattle raising. Each student was accompanied to his project and given suggestions as to methods of improving it and keeping record.

FAIRS

The extension agent assisted in securing and bringing the exhibits to and from the Territorial fair in Honolulu. He also acted as chairman of the committee which selected and conducted five delegates from the schools of the island of Hawaii to the Territorial fair. The delegates acted as representatives of their respective clubs and were chosen for outstanding work in cooking, sewing, poultry raising, vegetable gardening, and pig raising. Their expenses for the period were defrayed by the fair commissioners. In a fair held in the Hamakua district at the Honokaa junior high school in May, 1928, the extension agent acted as a judge of the exhibits displayed by the agricultural, home economics, and shop classes.

ASSISTANCE IN BOY SCOUT ACTIVITIES

The extension agent continued to serve as special examiner for boys qualifying for agricultural merit badges throughout the year and as scout commissioner and member of the traveling court of honor for a part of the year.

PLANTING WINDBREAKS

Seedling trees of eucalyptus, ironwood (*Casuarina* sp.), Monterey cypress, and black wattle (*Acacia decurrens*), grown at the Hilo nursery of the Territorial board of agriculture and forestry, were distributed to farmers living in the Hamakua, Waimea, and Kau districts. The high winds which blow almost constantly across these sections of the island constitute the worst drawback to the cultivation of diversified crops there. Growth is checked and the plants are weakened to such an extent as to make them susceptible to the attacks of pests and diseases. Vegetable gardeners and corn and potato growers find it profitable to devote a part of their lands to the planting of windbreak trees in parallel rows from 250 to 300 feet apart.

ASSISTANCE IN PLANTING FRUIT TREES

Citrus and avocado seedlings were budded with bud wood from the best locally grown trees, many of which were originally introduced into Hawaii. The budded trees were distributed to farmers in different parts of the island. Seedlings which had been started by homesteaders were budded and topworked on the farms where they are to remain permanently. The extension agent cooperated with agricultural instructors of the high schools by conducting demonstrations in budding and grafting and by securing material and choice wood from the better trees of the island. Papaya seed and banana suckers were given to interested private growers.

DISTRIBUTION OF SEED

Pigeon-pea seed was secured from the island of Maui and distributed to cattle ranchmen on the island of Hawaii for use in improving pasture and range lands. Corn seed was taken from the corn districts of Waimea and Kohala and distributed to schools and farms on the east side of the island. Cuttings and roots of the pasture grasses and forage crops that are maintained in the Kamuela grass plats were distributed to dairymen and homesteaders requesting them. Cuttings were also secured from the station in Honolulu for farmers in Hawaii. A supply of seed catalogues was distributed on field trips, and seed was purchased for farmers wishing to order new varieties from mainland seed houses.

DISTRIBUTION OF LITERATURE

Bulletins and circulars published by the station and the United States Department of Agriculture were distributed to farmers and schools in different parts of the island. Magazines and newspapers containing interesting articles on agricultural topics were loaned to farmers and to schools. Supplies of station bulletins and of

Farmers' Bulletins of the United States Department of Agriculture were loaned to agricultural instructors in the high schools for classroom work, and assistance was given in securing supplies for the teachers.

COFFEE

A further study of the coffee industry was made in response to requests from local growers for governmental assistance. A general survey of the coffee-growing areas was made, and the problems of coffee growers were ascertained through a number of personal interviews. Methods of coffee culture practiced by growers in other countries were studied to permit comparison with local methods and to determine the advisability of establishing cooperative experiments with growers.

REPORT OF BOYS' AND GIRLS' CLUB WORK

By Mabel Greene

STANDARD CLUBS

Boys' and girls' 4-H clubs were organized on the islands of Kauai, Oahu, Maui, and Hawaii. Four new club communities were added in Oahu. Activities among the 4-H club members in Maui increased, due to improved follow-up work.

The distribution of the boys' and girls' 4-H standard clubs of the islands is shown in Table 1.

Table 1.—*Enrollment of boys' and girls' clubs June 30, 1928*

Club	Oahu	Maui	Hawaii	Kauai	Total
Food preservation	26	38			64
Bread	15	20	19		54
Cooking	332	92	173	34	631
Clothing	84	112	32	14	242
Garden	6	54			60
Pig	30	80	7		117
Poultry		33	1		34
Rabbit	7				7
Horticulture					

Club activities were conducted in cooperation with the public schools with the teachers largely acting as leaders. Many of the clubs held meetings during the school season. In a few instances club leadership was not under school supervision. In Haiku, Maui, a pig club of 15 members had as leader Richard S. Gima, a 3-year 4-H pig-club member. In Makawao, Maui, Mrs. H. F. Willey conducted a very successful combined cooking and clothing club. In Honolulu, Maisie Leong, with a 5-year record as a 4-H club member, is leader of 15 girls in a cooking and food-preservation club that meets weekly during the summer and monthly during the school season. (Fig. 10.) The other clubs met every two weeks. The club leader assisted girl scouts who are interested in canning and food-preservation work. Two 4-H clubs were organized by two groups of girls in this work. Several of the girls were awarded canners' badges.

FAIRS AND DEMONSTRATIONS

The Territorial fairs were held from August 29 to September 5, 1927, and from April 30 to May 5, 1928. Committee activities, the training of demonstration teams for the fairs, caring for visiting delegates from the outlying islands, and preparing club exhibits added zest to club interests. Nine successful interisland 4-H club contestants attended the fall Territorial fair. The interisland members participated in gardening, poultry, canning, clothing, and bread-making contests. (Fig. 11.) A demonstration in making guava jelly and guavalets (guava candy) was given by a team of 4-H club girls. At the spring Territorial fair the junior branch was one of the more important features. The club leader acted as chairman of the home economics division and looked after the welfare of 14 visiting girl

FIGURE 10.—Alice Young and Maisie Leong. Pollyana 4–H club team

delegates forming part of the delegation of 31 boys and girls participating from the various islands and from Oahu. The visit of Miss Madge Reese of the United States Department of Agriculture in charge of boys' and girls' club work in the Western States, stimulated interest in fair activities. The judging of the junior-fair home economics exhibits was placed under her supervision. Demonstrations were given in boning and preparing chickens for roasting, "good buymanship," and grading eggs for market.

Under arrangements made by the Territorial fair commissioners, two 4-H club boys from rural Oahu entered heifer calves for exhibit at the junior Territorial fair. The boys camped on the fairground, cared for their animals, and enjoyed the educational program provided for visiting delegates from the various islands. Seichi Tamura, a member of the Kuhio pig club, of Honolulu, was awarded a silver cup for entering the best pig for exhibit in the junior Territorial fair. (Fig. 12.) The pig is one of the two registered Tam-

FIGURE 11.—Boys' and girls' 4–H club representatives from the other islands. Miss Greene and Mr. Willey, back row, right

FIGURE 12.—Seichi Tamura, Kuhio pig club member, awarded the silver cup for the best pig

worth boars that were purchased this year from the University of Hawaii farm. A silver cup was awarded a 4-H club boy for the best work in swine judging at the same fair. The 4-H clubs also had representatives in the poultry-judging contest at the fair. (Fig.

FIGURE 13.—Poultry club members grading eggs

13.) Much interest was shown in "Mrs. Ever-Well's medicine chest" displayed by the station. This exhibit was designed to encourage the use of more fruits and vegetables in the diet. Improved programs intensified interest in club work and prepared the way for larger community programs in the future.

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HAWAII AGRICULTURAL EXPERIMENT STATION
HONOLULU, HAWAII

Under the supervision of the
UNITED STATES DEPARTMENT OF AGRICULTURE

Washington, D. C. April, 1930

REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION, 1929

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SUMMARY OF INVESTIGATIONS

By J. M. WESTGATE, *Director*

During the fiscal year 1929 the station devoted its energies largely to the solution of problems vitally affecting the diversified agricultural industries of the islands. The agricultural extension activities of the station were transferred to the University of Hawaii because the various Federal appropriations for this work had been made available to the Territory of Hawaii through the University of Hawaii. The actual transfer of workers and activities was brought about throughout the year as rapidly as possible. With the inclusion of the Territory of Hawaii in the benefits of the various Federal appropriations under the Hatch, Adams, and Purnell Acts, plans were made by the United States Department of Agriculture and the University of Hawaii for the execution of a coordinated set of projects under a single director for the enlarged experiment station. These projects are to be financed from funds (1) appropriated direct to the Hawaii station through the United States Department of Agriculture, (2) accruing to the University of Hawaii through the application of the Hatch, Adams, and Purnell Acts, and (3) appropriated by the Territory of Hawaii to the University of Hawaii for the Hawaii station. It is felt that this arrangement,

effective July 1, 1929, marks a distinct step forward in the development of agricultural investigational activities in Hawaii.

In the horticultural division approximately 28,000 plants or packages of seed of improved varieties of fruits, nuts, and vegetables were distributed to local growers for trial. Sixty-eight different species of economic plants were introduced from the mainland and from foreign countries during the year, several varieties of each kind being obtained in a number of instances. Successful budding and grafting experiments were continued with coffee, the Macadamia nut, litchi, annonas, carambola, and *Eugenia* spp. Grafting and budding of these species are attended with much difficulty unless special precautions are taken. Considerable work was done looking toward the establishment of improved methods of propagating small plants which come true to seed. Certain kinds of plants that are usually propagated by cuttings were made the subject of special study. Studies of the varieties and pollination habits of the avocado and the papaya were continued. Much attention was given to the development of certain coffee experiments, and in this connection a number of the different species were assembled for use in hybridization work and in determining the relative merits of the different species as rootstock material. One of the most interesting investigations of the year was that undertaken with the large native raspberry, locally known as the akala (*Rubus hawaiiensis* and *R. macræi*). Under favorable conditions the individual fruits attain a maximum diameter of 2 inches. Numerous seedlings are now being tested at various elevations. The Macadamia nut tree is receiving increasing attention from commercial growers, and every effort is being made to solve the various problems in connection with its commercial development.

Work in the chemical division was again concentrated on various problems dealing with the edible canna starch industry. A brief survey of the coffee soils in the Kona district, Hawaii, was made. A study was made of the soil colloids in representative soil samples obtained from various locations throughout the Hawaiian Islands. A preliminary survey was also made to determine the regions best adapted to the commercial production of edible canna. Analyses of 28 kinds of range grasses and forage crops were completed. Chemical studies of Macadamia nuts from various seedling trees indicate the need of standardizing the crop for commercial use. The fruit was found to vary widely in oil and sugar content. A method based on the specific gravity of the nuts was worked out permitting the separation of the nuts from each tree into different grades of maturity.

Agronomic work centered largely on field crops which give promise of aiding the development of diversified agriculture in the islands. Seven different varieties of edible canna were grown in comparison with other root crops, including cassava, ginger, taro, kudzu, and sweetpotatoes. One hundred and thirty varieties of sweetpotatoes were under test. To determine their value as forage crops, Napier grass, Merker grass, Mexican grass, and Kikuyu grass were tested during the year. Some attention was given to a study of the best methods of utilizing rice lands that are being abandoned because of the depredations made upon the crop by the rice borer. Other activities included corn breeding, attempts to develop a solid-headed

strain of lettuce for the lower altitudes, tests with green-manuring crops, a study of the effect of chemicals on weeds, and investigations of the cultural requirements of certain oriental vegetables. The agronomist continued to assist local poultrymen with their poultry problems and helped to stage the Maui and Kauai poultry shows in October and again in December, 1928.

At the Haleakala substation attention was again given to the solution of various agricultural problems of interest to the island of Maui. Some 188 varieties of 60 different kinds of crops were tested. Distribution of small lots of planting material of improved strains under test was an important part of the work of the year. Efforts are being continued to develop strains of pigeon peas that will mature at the higher elevations throughout the islands. Studies were made to determine the effect of different green-manure and cover crops and of different fertilizers on yield of pineapples. Partly as a result of the work of the substation, the Maui pineapple plantings have been extended to areas several hundred feet higher than it was previously thought possible to grow the crop. In an effort to enlarge the area in pineapples, cooperative experiments were undertaken at an elevation of about 3,300 feet near Olinda on the slopes of Haleakala. Experiments were continued to determine the cultural requirements of edible canna as a promising source of commercial starch.

During the year the extension activities of the station, including the 4–H club work, were gradually transferred to the University of Hawaii, which now receives the benefit of the Smith-Lever and other Federal appropriations for agricultural extension work.

REPORT OF THE HORTICULTURAL DIVISION

By W. T. Pope

TROPICAL FRUITS

INTRODUCTIONS

The introduction of tropical fruit trees was not large in number of species as compared with that made in previous years, but some of the additions are valuable, and a number of them are new to Hawaii. Of 68 different species introduced, the following are listed.

The marang (*Artocarpus odoratissimus*), a seeded form of breadfruit from the Philippines, said to be a very large ornamental and fruit-producing tree of considerable value; the lanzon (*Lansium domesticum*), a small fruit tree of considerable importance in the Philippines and parts of tropical Asia; the Macadamia nut (*Macadamia ternifolia*), a thin-shelled variety from Australia; the rednut (*Hicksbeachia pinnatifolia*), a handsome ornamental tree which produces edible nuts; Tinospora (*T. crispa*), a medicinal vine from the Philippines; the butternut (*Juglans cinerea*), a common native of the Southern States; the kawa (*Nephelium pinnatum*), a fruit tree which was introduced from Tahiti; the akala (*Rubus hawaiiensis*) from Mount Puu Hualalai, elevation 5,500 feet, on the island of Hawaii; the Vangueria (*V. edulis*), which was introduced from the island of Tahiti; the chestnut (*Castanea vesca*) from the eastern part of the United States; the black walnut (*Juglans nigra*) from the central part of the United States; the Tahitian coconut (*Cocos*

nucifera) from the Society Islands; coffee, including 21 seedlings of *Coffea robusta*, 50 seedlings of *C. arabica*, and 1 seedling of *C. excelsa*, from Tanganyika, Africa, through the United States Department of Agriculture; seeds of the Madame Russell papaya (*Carica papaya*) from the island of Haiti, West Indies, through the United States Department of Agriculture; seeds of an unusually fine-fruited tamarind (*Tamarindus indica*) tree from the Philippines; the varieties of raspberry (*Rubus* sp.) Cuthbert, Marlboro, Latham, Ranere (*St. Regis*), Columbia, Gregg, Cumberland, and Salmonberry from Sumner, Wash., 25 Cumberland raspberry plants from Wondervine farm, Ohio, 25 Cuthbert raspberry plants from the Western Washington experiment station, and 4 Kansas raspberry plants from the State experiment station, Manhattan, Kans.; the pili nut (*Canarium polyphyllum*) from New Guinea; the rukam (*Flacourtia rukam*) from the Society Islands; tomato (*Lycopersicum esculentum*) seed of the variety Bountiful from Germany, through R. Behrns; and breadfruit (*Artocarpus incisa*) root cuttings of the varieties Hamoa, Rare, Paere, and Maire from the Society Islands.

DISTRIBUTIONS

Approximately 28,000 plants were distributed to cooperative experimenters during the year. Many species of unusual value, either improved or new to the island, were distributed as a means of getting them into cultivation. The distributions included mainly avocado seedlings and grafted trees, banana propagating material of different varieties, carambola seedlings of both sweet and sour fruited varieties, carissa, cashew, cherimoya, coffee, date seedlings, fig cuttings, *Passiflora* spp., Isabella grapevines, several kinds of guava, grafted lemon trees, seedling lime trees, seedling litchi, egg fruit, mabolo, mango grafts and seedlings, mountain-apple seedlings, mulberry cuttings, Macadamia-nut seedlings, grafted orange trees and Hawaiian seedling oranges, papaya seedlings, Surinam-cherry, Brazil cherry, pomegranate plants, grafted grapefruit, grafted shaddock, rose-apple trees, roselle plants, sapodilla plants, soursop plants, star-apple seedlings, tomato plants (station hybrid), and the tree-tomato.

KINDS UNDER OBSERVATION

A study was made of a number of fruit plants both at the central station in Honolulu and with cooperative experimenters throughout the Territory. An annotated list of the plants under observation is given herewith.

Akala (*Rubus hawaiicnsis*).—Seedlings of the akala are under cultivation for the first time at the central station. The seeds germinated and the young seedlings are growing very well. Some of them have been placed at the Tantalus substation (1,000 feet elevation) for further growth. Their early growth there is satisfactory.

Avocado (*Persea americana*).—During the year several thousand avocado seedlings were raised from both West Indian and Guatemalan seeds. Part of these have been used for grafting experiments. Some grafting work was also done on seedlings developed the previous year.

Banana (*Musa sapientum*).—Banana requirements have been rather thoroughly worked out in previous years, but planting material is still under cultivation and observation at the station.

FIGURE 1.—Fruit cluster of bignay (*Antidesma bunius*). Tree fruited at the station in 1928

Barbados cherry (*Malpighia glabra*).—The Barbados cherry has never been found to be of importance in the Territory, but it is now on trial at the station.

Bignay (*Antidesma bunius*).—The bignay was introduced into Hawaii by the station some years ago. The trees have fruited heavily at the Tantalus substation.

Brazil cherry (*Eugenia brasiliensis*).—The Brazil cherry grows well in many parts of the Territory at the lower elevations. It requires a deep, moist soil.

Carambola (*Averrhoa carambola*).—Trees of both the sweet and sour varieties of carambola have been under cultivation at the station and fruited freely during the year. Seedlings have also been grown in the nursery.

Carissa (*C. arduina*).—Carissa plants of considerable size are growing at various places in the station grounds. They thrive in a variety of soils and fruit freely, particularly at the lower elevations.

Carob (*Ceratonia siliqua*).—Carob trees have been tested at the station for some years but they grow slowly.

Cherimoya (*Annona cherimola*).—The cherimoya is under cultivation at the station but the elevation is too low for rapid growth and prolific fruiting habits. The cherimoya makes its best growth at elevations of 1,000 to 2,500 feet where the rainfall is moderate.

Citron (*Citrus medica*).—Citron grows to some extent in the Territory. Two trees are on trial in the station citrus orchard.

Cocoa (*Theobroma cacao*).—Cocoa trees are being tried in the station orchard, but they are too exacting in their requirements for station conditions. They require a warm, moist soil and climate.

Coffee (*Coffea* sp.).—Coffee has been on trial at the Tantalus substation for many years. During the year seedlings of several different species were under development at the central station nursery, and a large number of them were transplanted to the Tantalus substation.

Bullock's-heart (*Annona reticulata*).—One tree of bullock's-heart is growing in the station orchard and is fruiting rather freely.

Date (*Phœnix dactylifera*).—The date tree does well in many parts of the Territory, especially in the hot, dry localities where irrigation water can be furnished. Date seedlings of hybrids, introduced the previous year, were grown at the central station. A portion of the supply was distributed to cooperative experimenters.

Fig (*Ficus carica*).—Fig trees of a number of varieties are on trial at the central station and at the Tantalus substation, and cuttings are occasionally rooted to permit distributing these varieties for general culture in various parts of the Territory.

Granadilla (*Passiflora quadrangularis*).—The granadilla vine is on trial at the Tantalus substation. The plants furnish propagating material for distribution.

Grapes (*Vitis* sp.).—The grape experiments which have been carried on for the past several years were concluded. The Isabella is the only variety that is resistant to soil conditions. Successful grape growing is somewhat hindered by the Japanese beetle which feeds on the foliage in some localities. It has been controlled to some extent by spraying the plants with water at the approach of darkness. Grape growing is very successful in localities where evening showers are frequent.

Guava (*Guava* spp.).—Several species and varieties of guava are grown throughout the Territory and have been under test at the experiment station.

Java plum (*Eugenia jambolana*).—The Java plum has received very little attention, although many variations of it are grown

throughout the Territory. Several trees have been fruiting under observation at the Hawaii station.

Jujube (*Ziziphus jujuba*).—Some species of jujube have been cultivated in Hawaii for many years and trees of considerable size can be found in Honolulu. New varieties introduced by the station have not been successfully grown. During the year some of the plants were distributed for cultivation at various elevations.

Kumquat (*Citrus japonica*).—The kumquat is successfully grown along with other kinds of citrus in the Territory. None is under test at the station.

Lanzon (*Lansium domesticum*).—Small seedlings of the lanzon tree of the Philippines are now being developed at the central station.

Lemon (*Citrus limonia*).—The station has a number of varieties of lemon trees under cultivation, and they fruit abundantly but are seriously attacked by gum diseases. For many years they have been used as a source of graft-wood material for use in carrying on experimental work.

Limes (*Citrus aurantifolia*).—A number of varieties of limes are growing in various parts of the Territory. Trees of most of these varieties have been under test at the station. Perhaps the favorite is the Kusaie, which does unusually well at the station, but is attacked to some extent by the fruit fly.

Litchi (*Litchi chinensis*).—A number of varieties of litchi are under test at the station. Seedlings have been raised for grafting experiments. The litchi does unusually well at 1,000 feet elevation in the Kona district, Hawaii. It is exacting in its requirements, however, and for that reason its culture has not been extended to most localities.

Loquat (*Eriobotrya japonica*).—The loquat is easily grown in many parts of the Territory and has been under test and observation at the Tantalus substation for many years. The fruit is a very favorable host for the fruit fly and has received little attention in recent years for this reason.

Lucuma (*Lucuma obovata.*)—The lucuma, or egg fruit, is very successfully grown locally, but has not as yet met with much favor.

Longan (*Euphoria longana*).—The longan is grown to some extent in many parts of the Territory. In several localities the trees fruit abundantly. Longan trees have been grown on the station grounds for years but have never come into fruit.

Mabolo (*Diospyros discolor*).—The mabolo tree was recently introduced into Hawaii from the Philippines. The young seedlings have been distributed to interested growers and are reported to be in fruit. Specimen trees in the station orchard are blooming this year. (Fig. 2.)

Mamey (*Mammea americana*).—The mamey apple tree attains considerable size and grows in many parts of the Hawaiian Islands, particularly at the lower elevations. It fruits freely, but the fruit is not generally a favorite. A single tree is growing in the station orchard.

Mango (*Mangifera indica*).—The mango, which is one of the leading fruit trees of Hawaii, has been under experiment at the station for many years. A small orchard of the trees is being maintained

to permit a study of their culture and as a source of grafting material.

Mangosteen (*Garcinia mangostana*).—The mangosteen is now grown in several places in the Territory but is too exacting in its requirements to suit every locality. Seedlings introduced by the station usually failed to withstand local conditions.

Monstera or ceriman (*Monstera deliciosa*).—The ornamental monstera is under observation at the station. It is again fruiting freely, but as yet the fruit has met with little favor.

Mountain apple (*Eugenia malaccensis*).—A study of the mountain apple indicates that it will grow in a great variety of climates and soils. The fruit is valuable, and the trees are beginning to be generally grown in the home gardens. The mountain apple has been

FIGURE 2.—The mabolo (*Diospyros discolor*) which fruited in Hawaii in 1928 for the first time

under cultivation for years at the Tantalus substation, and each year many seedlings have been grown in the nursery for distribution.

Mulberry (*Morus nigra*).—A number of mulberry trees have been experimented with and have proved to be a source of propagating material. Many rooted cuttings are distributed each year.

Macadamia nut (*Macadamia ternifolia*).—The Macadamia nut tree is becoming popular and received considerable attention during the year. Several trees at the Tantalus substation have been the source of propagating material. During the year grafting experiments were in progress.

Orange (*Citrus sinensis*).—The varieties of orange Washington Navel, Ruby, Valencia, and Hawaiian seedlings, are all under test in the station orchard. The orange can be grown satisfactorily in parts of Hawaii where it can have considerable warmth and an abundance of soil moisture.

Papaya (*Carica papaya*).—Papaya investigations were completed during the year and the results prepared for publication in bulletin form.

Peach (*Amygdalus persica*).—Several peach trees are growing in the station orchard but have not as yet come into bearing. The peach tree bears freely in different parts of the islands, but the fruit is seriously attacked by the fruit fly.

Pejibaye (*Guilielma utilis*).—The pejibaye palm, which is a rather recent introduction, is now growing at the station. A number of the seedlings have been distributed to interested growers living in localities that are believed to be similar to those native to the plant.

Persimmon (*Diospyros* spp.).—Both the Asiatic persimmon (*D. kaki*) and the black persimmon (*D. ebenaster*) are grown in a few localities in Hawaii. The latter is now growing at the station.

Poha (*Physalis peruviana*).—The poha grows in many of the moist localities at elevations between 1,000 and 4,000 feet.

Pomegranate (*Punica granatum*).—The pomegranate grows to perfection in some parts of the Territory. Several varieties have been under test at the station for several years, but the fruit is not considered to be of much value.

Pomelo (*Citrus decumana*).—Good grapefruit and shaddock are sometimes produced both in the station orchard and by growers throughout the Territory.

Roselle (*Hibiscus sabdariffa*).—The roselle, as a jelly plant, is little grown in Hawaii. The experiments which have been in progress for some time at the station have been discontinued.

Sapodilla (*Achras sapota*).—Two sapodilla trees are to be found growing at the station. The sapodilla fruits abundantly in many parts of Hawaii, but the fruit is rather insipid and considered to be of little value.

White-sapote (*Casimiroa edulis*).—One tree of the white-sapote occasionally fruits at the station. Its fruit is of little value. However, there are seedling trees of white-sapote in the Territory that produce a more highly flavored fruit.

Seagrape (*Coccoloba uvifera*).—The seagrape grows at the station, but the fruit is of little value.

Soursop (*Annona muricata*).—The soursop grows well at the lower elevations and some of the seedling trees produce fruit of very desirable flavor.

Star-apple (*Chrysophyllum cainito*).—Considerable attention has been given to the star-apple and the fruit has been favorably received by some.

Strawberry (*Fragaria chiloensis*).—Strawberries have been under observation at the station. They do not do well at the lower elevations. At an elevation of 1,200 feet the plants produce abundant fruit of good quality.

Tahitian chestnut (*Inocarpus edulis*).—A few Tahitian-chestnut trees grow in the Hawaiian Islands. A number of small plantings are being developed at the station.

Tomato (*Lycopersicum esculentum*).—Experiments with the tomato have been discontinued with the exception of the growing of the station hybrid, the result of a cross between the well-known Earliana and a wild tomato. This hybrid is being maintained at

the station, and some effort given to its improvement by seed selection.

Tree-tomato (*Cyphomandra betacea*).—The tree-tomato is worthy of more consideration in this Territory than it now receives. It does well in some localities and the fruit sells readily.

Vanilla (*V. planifolia*).—Specimen plants of vanilla are being grown in the slat-propagating house at the station. Vanilla production has been a small industry in Hawaii for a number of years.

Waterlemon (*Passiflora laurifolia*).—The waterlemon, although an introduced plant, now grows wild in the woods in some parts of the islands. It is frequently under test at the station, and plants have been distributed to interested growers.

Wi-fruit (*Spondias dulcis*).—The wi-fruit has been under cultivation in the Hawaiian Islands for many years. One wi-fruit tree is growing in the station orchard.

METHODS OF PROPAGATION INVESTIGATIONS

Many kinds of fruit trees which are grown in limited areas in Hawaii might be developed commercially. Perhaps the most vital horticultural factor governing commercial orchard production is the determination of suitable propagation methods. For several reasons fruit-tree propagation is unusually complicated. Most of the fruit trees now growing in the Hawaiian Islands have fixed characters which are peculiar to the parts of the world whence they came. The seeds of some trees are adapted for germination under very moist conditions, whereas others require dry conditions. Certain nuts and other kinds of seed germinate very slowly, having been adapted to withstand the long, cold winters of the Temperate Zone. In vegetative propagation by means of cuttings, budding, grafting, and the like, the requirements vary considerably.

Soil mediums for seed.—Coral sand, volcanic sand, and various kinds of composts were used as soil mediums for seed propagation at the station. Coral sand consists of the broken coral rock of the reef. The particles vary in size and are more or less smooth as the result of action by the sea. The sand particles may be screened to meet the requirements of different kinds of plants. Clean coral sand contains very little available plant food. However, this sand when properly moistened has good water-holding capacity and is porous enough to permit a free circulation of air throughout. Under normal Hawaiian temperatures these conditions give warmth, moisture, and oxygen sufficient for the chemical changes taking place in the germination of seeds and the rooting of many kinds of cuttings. Coral sand, being composed largely of lime, is believed to have a preventive effect upon the growth of certain parasitic fungi, commonly known as damping-off disease, which sometimes attacks young seedlings and tender cuttings. For the same reason the surface of the sand when used in propagation is slow in becoming sealed over with a dark green or blackish algae.

Volcanic sand and cinders are commonly called "black sand." Volcanic sand is produced by the action of the sea which breaks comparatively recent lava flows into a smooth-grained sand and builds it above sea level into black sand banks. Cinders are the fragments

of scoriaceous lava which are explosively ejected by volcanoes during an eruption and fall in layerlike deposits over the mountain slopes. The cinder medium is sharper and possibly better adapted for propagation work than are other kinds of mediums. Like the coral sand, the cinder particles vary in size and may require screening before they are used for propagating certain kinds of small and tender seeds. Seeds that have been successfully germinated in flats 12 inches wide by 16 inches long by 3 inches deep include those of the tomato (*Lycopersicum esculentum*), rubus (*Rubus* sp.) carambola (*Averrhoa carambola*), carissa (*Carissa arduina*), guava (*Psidium guajava*), pepper (*Capsicum* sp.), poha (*Physalis peruviana*), roselle (*Hibiscus sabdariffa*), passion fruit (*Passiflora* sp.), algaroba (*Prosopis juliflora*), Philippine berry (*Mutinga calabura*), papaya (*Carica papaya*), and the tree-tomato (*Cyphomandra betacea*). When only a few seeds were to be germinated, shallow flowerpots were used. These containers were placed in an insect-proof glass-covered house where both moisture and temperature could be controlled. Seeds requiring a longer germinating period than those mentioned were placed in a 1-inch layer of coral sand which was overlaid by a 2-inch layer of rich potting soil. The soil contains a greater amount of plant food and stimulates root growth, which then becomes sufficiently established to withstand transplanting to individual containers.

Medium coral sand and medium black sand were separately used for some of the above-mentioned seeds and also for the seeds of the lime (*Citrus aurantifolia*), orange (*Citrus sinensis*), lemon (*C. limonia*), pomelo (*C. decumana*), pomegranate (*Punica granatum*), bignay (*Antidesma bunius*), Brazil cherry (*Eugenia brasiliensis*), carob (*Ceratonia siliqua*), coffee (*Coffea* spp.), date (*Phœnix dactylifera*), mountain apple (*Eugenia malaccensis*), Surinam-cherry (*E. uniflora*), rose apple (*E. jambosa*), sapodilla (*Achras sapota*), black-sapote or black persimmon (*Diospyros ebenaster*), white-sapote (*Casimiroa adulis*), soursop (*Annona muricata*), star-apple (*Chrysophyllum cainito*), and mango (*Mangifera indica*).

Coarse black sand and coarse coral sand were used separately as mediums for the cashew nut (*Anacardium occidentale*), Macadamia nut (*M. ternifolia*), pecan nut (*Carya olivæformis*), black walnut (*Juglans nigra*), butternut (*J. cinerea*), Tahitian chestnut (*Inocarpus edulis*), and Japanese chestnut (*Castanea sativa*).

Special soil mediums were prepared for seeds of unusual requirements. In such soils grated coconut husk, pulverized peat, or sphagnum moss were used to increase the water-holding capacity of the mediums. This is often necessary for very soft seeds of certain fruits from moist, tropical regions. These mediums were used successfully with the lanzon (*Lansium domesticum*), litchi (*L. chinensis*), longan (*Euphoria longana*), and *Eugenia* sp.

Certain kinds of seeds germinate best if they are placed in large propagating benches of coral sand in the open sunlight. At the station these benches were 1 foot deep, 3 feet wide, and 12 feet long. The sand in these benches was sufficiently deep to allow for natural and early extension of the taproot of such seedlings as the avocado and the Macadamia. These attain a length of 6 or 8 inches before forming any side roots. A deep medium also enables the air to cir-

culate freely in the soil. Exposure of the seed bed to the sunlight tends to develop stocky seedlings of a size suitable for early grafting. These seedlings may be successfully transferred to gallon containers in 20 or 30 days after the seed is planted. In transplanting the taproot may be cut back to within 4 or 5 inches to induce a more rapid development of the side roots. After 10 to 15 days in the gallon containers, the avocado plant is of sufficient size for grafting. Macadamia nuts germinate well under these conditions and produce hardier seedlings than when they are grown in soil under partial shade. Deep sand mediums have also been found very satisfactory for rooting cuttings of the Isabella grapevine and other hardwood cuttings.

Vegetative propagation.—Fruit tree vegetative propagation methods, by the rooting of cuttings and by grafting, have been under investigation as a means of rapidly increasing and standardizing certain desirable varieties.

Mature hardwood cuttings were successfully rooted when they were placed in an 8 to 10 inch coral-sand medium in benches in the open sunlight. These cuttings included the fig (*Ficus carica*, three varieties), the Isabella grapevine (*Vitis labrusca*), black mulberry (*Morus nigra*), and granadilla (*Passiflora quadrangularis*). Cuttings of *Carica papaya* were tried in similar deep mediums in the glass-covered house but gave only a small percentage of success. Cuttings taken from the surface roots of seedless varieties of breadfruit (*Artocarpus incisa*) are now rooting. These root cuttings were collected in the Society and Cook Islands, South Pacific Ocean, by G. P. Wilder. The cuttings were about 1½ inches in diameter and 6 inches long and were placed horizontally several inches below the surface of the sand and about 1 inch above a 4-inch layer of fairly rich garden soil. The percentage of success with these cuttings has been relatively large, especially when it is considered that the material was in transit for 36 days, and in some instances was out of the soil for a much longer period.

The grafting of avocado seedling nursery stock varying from 50 days to 14 months from the date of planting the seeds was tried during the year. In the use of the younger material, stock 50 to 60 days old was grafted with medium-tender scions which were taken from the terminals of comparatively new branches of trees of desirable varieties. Cleft or wedge grafting and whip grafting were the two methods used. (Fig. 3, A and B.) In cleft grafting the seedling was cut off squarely about 5 or 6 inches above the ground and the remaining stub was split 1½ or 2 inches to receive the wedge-shaped basal end of the 2½ or 3 inch scions. In whip grafting the stock was cut off at an angle, giving a beveled surface of about 1½ inches in length. In this surface a ¾-inch wedge-shaped tongue was cut to receive a similar tongue made in the beveled surface of the basal end of the scion. One of the most important parts of the entire operation is the selection of scions in a suitable condition of growth. The possibilities of such condition depend greatly upon the season. Although the methods of grafting mentioned were true to name, different methods were employed in binding and covering the unions. Some were bound with only enough raffia to hold them firmly; with others the material was wrapped so as to cover the union completely.

Experiments indicated that the best results were obtained by protecting the bound union, including the entire surface of the scion, with a covering of melted paraffin applied with a brush or as a spray. Wrappers, made from ½-inch strips of white muslin previously dipped in melted grafting wax, and from strips of elastic mending tape, such as is used by tailors, were also used. Another method now giving fairly good results consists in using as binders strips one-half inch wide and 5 inches long cut from old automobile-tire tubes. These strips are stretched tightly about the union with the end tied in what is known as a half hitch. The bandage naturally

FIGURE 3.—Methods of grafting used in standardizing nursery stock at the station: A, Whip grafting; B, cleft or wedge grafting; C, side-tongue grafting; and D, bark grafting

contracts enough to form a tight wrapper. After 10 to 14 days the wrappers are removed.

The various grafting experiments were 35 to 92 per cent successful. The best results in grafting young nursery stock were obtained by using a tight raffia binder and coating the entire surface of the union and scion with a thin layer of melted paraffin. All the unions were satisfactory when both stock and scion were in good condition. The seedlings used in the experiments included the West Indian, Guatemalan, and hybrid kinds. Hybrids which are the result of crosses between Guatemalan and West Indian varieties gave the best results.

The varieties were grafted to the seedlings of the West Indian types Bromley, Seyde, Wilcox No. 3, Isenberg, Preston, Osborn,

Marques, Lewis, Enoi, Lando, Berger, Tantalus, and Trapp; Guatemalan types Macdonald, Nabal, Panchoy, Ishkal, Nimlioh, Kashlan, Kanan, Benik, Mayapan, and Tumin; and hybrids Beardslee, Haley, Ilialu, Lehua, Kinau, and Nutmeg.

A very satisfactory method of side-tongue grafting young mango nursery stock has been employed to increase the number of hybrids. This method of grafting was worked out by the station several years ago and is now generally practiced at the station and by a number of private growers. It is best accomplished with 6 to 8 months old seedlings grown in gallon containers. Such seedlings usually have a stem diameter of about three-eighths inch and a height of about 18 inches. The graft is made in the side of the stem at a distance of 4 or 5 inches above the ground. (Fig. 3, C.) The scion wood should be healthy, clean, plump, firm, and of the same diameter as the stock where it is united. The union is bound firmly with raffia and the whole outer surface of the union, including the tying material, is coated with paraffin. Part of the terminal growth of the stock is then pruned to retard growth at that point. As soon as the leaves put out by the scion have made sufficient growth to function, the rest of the top of the stock is cut off just above the union. The cut surface is then coated with grafting wax. About four to six weeks later the young grafted tree is ready to be set in permanent place in the orchard.

Several other methods of grafting the mango were tried, including cleft or wedge grafting, and bark grafting, but none of them was very successful.

Vegetative methods of propagating nursery stock of citrus varieties were tested during the year. Sour orange and shaddock (*Citrus maxima*) were used as the seedling stock. The latter has proved to be the most vigorous of the several rootstocks tested. Seedlings of several varieties of grapefruit were used and the grafted trees made satisfactory growth but their disease-resistant ability and adaptability to local conditions still remain to be determined. The lime varieties grafted were the Tahiti, Bearss (improved Tahiti), and Kusaie; and the lemon varieties, the Villafranca (rough lemon), and Sweet Lemon, a local variety which was until recently new to the station. Six to eight months old seedlings were grown in gallon containers for bark grafting. In grafting, the seedling is cut off at about 4 inches above the ground and the scion of the desired variety is cut at an angle from one side to the basal end so as to form a beveled surface 1½ inches long. The scion is slipped down inside the bark, which spreads to each longitudinal cut. The union is then firmly bound and the whole union is given a thin coating of melted paraffin. This method is very satisfactory and has in many trials given a large percentage of success. (Fig. 3, D.) The same methods were employed also in grafting the Victoria variety of shaddock, a sweet-shaddock variety, and the Marsh and Foster varieties of grapefruit.

Orange varieties grafted during the year included the Valencia, Navelencia, Hawaiian seedlings, Thomson, Washington Navel, and Golden Buckeye.

Other kinds of trees grafted included the litchi, annonas, Macadamia nut, Eugenias, and carambola. Litchi seedlings from

seed planted in June, 1927, were of good size in January, February, and March, 1929. A number of side-tongue graftings and bark graftings (fig. 3, C and D) were employed successfully. The first mentioned, however, was most successful and resulted in about 25 per cent of successes. It is believed that this method may be eventually worked out as a successful means of locally standardizing the litchi tree for commercial planting. Both longan and litchi stock have been employed in Hawaii in this work, and the lack of disease resistance in the litchi stock has not been found to be an obstacle to the successful culture of this fruit in these islands. (Fig. 4.)

Bullock's-heart (*Annona reticulata*) and cherimoya (*A. cherimola*) were grafted during the year. (Fig. 4, E.) Several trees of each species have been growing in the station orchard for some years.

FIGURE 4.—Fruit trees grafted as a means of standardizing the crops: A, Avocado; B, citrus; C, mango; D, coffee; E, cherimoya; F, Macadamia; and G, litchi

Local conditions are in part suitable for the *A. reticulata*, but the *A. cherimola* does not grow well and does not fruit at the lower elevations. It fruits satisfactorily at altitudes approximating 3,000 feet on the island of Hawaii.

Very little progress was made in the work of grafting Macadamia-nut seedlings because little seedling stock was available for use at the station. However, 800 Macadamia seedlings are now approaching a size suitable for experimental grafting purposes. The seedless water apple (*Eugenia aqua*) was experimented with during the year. The tree is handsome in foliage and flower, and the fruit has possibilities for use as a food. An effort was made to graft it on mountain-apple seedlings, and while the results are encouraging, no great amount of success can as yet be reported. At this writing (June 30, 1929) only one plant appears likely to succeed. The two species, although

related, do not appear to be congenial. Some other related species will be tried as rootstock material. Several improved varieties of *Eugenia malaccensis* indicate the importance of finding a vegetative method for establishing varieties of this useful tree.

AVOCADO AND PAPAYA VARIETIES AND POLLINATION HABITS

Renewed interest in the avocado has resulted in a more thorough study of the varieties of this fruit, and in efforts to establish prolific varieties yielding fruit of high quality having good flavor and being fiber-free. In addition to the studies made by the station, the Hawaiian Avocado Association has appointed a committee to make a study of such varieties as are desirable for general planting. During the year several new hybrids, including the Pratt, were produced and may eventually be propagated. (Fig. 5.)

A small planting of about 30 avocado seedlings at Schofield Barracks at an elevation of about 1,100 feet has attracted considerable attention. These trees are from the seeds of the hybrid Wilder, which is the result of crossing the Macdonald, a Guatemalan type having rough, thick rind, with a West Indian smooth-skinned type. The Wilder has many characters of the mother tree, the Macdonald. The fruit of the Wilder seedlings at Schofield, Oahu, shows some variation, but in general it is much like that of the Wilder. The nature of growth of the seedlings on a high plateau indicates that the environment is suitable, but under the same conditions the growth of West Indian avocados of pure strain is very unsatisfactory.

The matter of pollination seems to be of no concern with the avocado trees at Schofield Barracks, but it is of paramount importance at the Tantalus substation, where many of the trees have failed to set fruit notwithstanding the fact that most of them have blossomed freely every spring for the past five years. In the Tantalus orchard there are 15 introduced Guatemalan varieties, 24 West Indian varieties, and 4 hybrid varieties. Failure of the trees in this orchard to set fruit is no doubt influenced partly by their failure to receive sufficient moisture for the crop. The orchard is located on a steep hillside, and the rain does not percolate through the soil to the root zone unless it falls slowly and steadily. A permanent cover crop of *Commelina nudiflora* has been planted in the orchard in an effort to prevent surface washing.

Much time was devoted to a study of the habits of pollination of the papaya (*Carica papaya*). Pollination and fruit qualities are so closely associated as to make it useless to study the one without also studying the other. During the several years these studies have been in progress the plants have been found to vary widely in character and to produce somewhat irregular fruits. This year, as in other years, it was observed that failure of pollination to take place at some time during the year resulted in some of the plants becoming more or less sterile and that the seedless fruit which was set by some plants without fertilization was usually thin in flesh and poor in flavor. The results of investigations during the year showed that the papaya is subject to mutations and that in pollination the flowers cross freely and display marked evidence in the fruit of the first generation. A small trial orchard of 90 plants set in 1928 has given considerable propagating material for study.

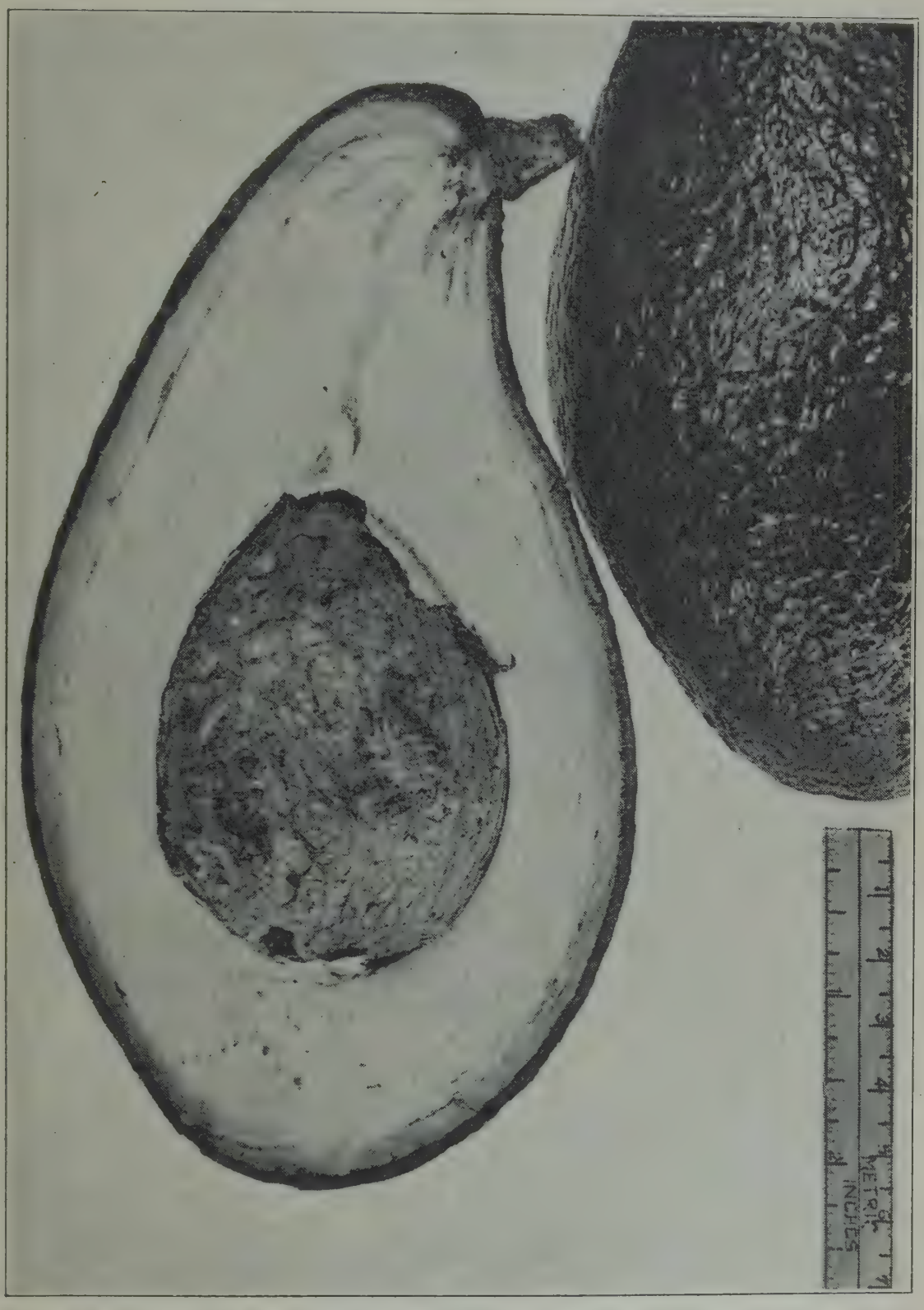

FIGURE 5.—Promising new hybrid avocado, Pratt, which is the result of crossing a Guatemalan and a West Indian variety

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Notes were made of any great variation in stamens as to length, the nature of anthers, and the condition of pollen. Stamens present in pistillate fruit were found to be closely associated with form of fruit. Cultivated papaya plants from carefully selected seeds of dioecious plants tend to have the greatest number of pistillate or fruit-bearing plants.

COFFEE

Renewed interest in coffee growing in Hawaii during the past few years has brought about considerable investigation of the industry. The great variations noted in the yields and grades in the different commercial plantings indicate the importance of using cultural methods for the crop.

Practically the same problems confront the planters in several of the leading coffee-growing countries, and in some places, notably in the Dutch East Indies, the difficulties have been overcome, at least in part, by grafting desirable varieties on resistant rootstocks. The presence of nematodes in Hawaiian soils adds to the problem of developing resistant rootstocks. It is also believed that a study of the relative merits of such species and variations as are adapted to Hawaii is important for improvement of the industry.

Some 779 seedling trees of 3 species and 5 so-called varieties are now under study at the station. Eighty trees of Hawaiian coffee (*Coffea arabica*) and 7 trees of Robusta (*C. robusta*) are growing at the Tantalus substation. The trees of these 2 species are now about 19 years old. Young seedling coffee trees which were set in March at the Tantalus substation included 50 Tanganyika trees (No. 5381)[1], 4 Guatemalan trees (No. 4135), and 60 Hawaiian trees (No. 5383) of the Arabian group (*C. arabica*); 13 Excelsa trees (No. 5382, 1 tree, and No. 3947, 12 trees) of the Liberian group (*C. excelsa*); and 1 Robusta tree (No. 3948) of the robustoid group (*C. robusta*). Remaining in the nursery are 3 Excelsa trees (No. 3947), 1 Guatemalan tree (No. 4135), 1 Java hybrid (No. 3941), and 540 Hawaiian trees (No. 5383).

About 50 of these trees are being used in the grafting experiments and about 140 have been given out for cooperative experiments.

During the early spring about 60 cuttings were put into coral sand, one lot being placed in the glass-covered house and the other in the slat propagation house among larger plants. Most of these failed to make any leaf growth, whereas others produced leaves and soon died. Six are still in the sand but do not appear to be rooting. The leaves produced were developed on the plant food stored in the tissues of the cuttings, there being no roots to support them. About fifty 2-year-old seedlings growing in gallon containers were grafted by the side-tongue grafting method, such as is employed successfully in grafting avocado and mango seedlings. (Fig. 3, C.) The percentage of success was small. The experiment has not yet been continued long enough to give definite results. Former experiments in Hawaii and elsewhere have fully demonstrated the possibilities of grafting nursery stock and old coffee seedlings and of successfully top-working old trees in established coffee orchards.

[1] Number under which the trees were received at the station.

AKALA OR NATIVE RASPBERRY

A greater production of locally grown foodstuffs is needed to satisfy the requirements of the population of the Hawaiian Islands which is increasing at the rate of about 15,000 persons per year. Many of the locally grown horticultural crops seem to have cultural possibilities looking toward the development of small industries which would help to meet these requirements. The successful growth of the native raspberry (*Rubus* sp.), or akala as it is called locally, indicates that it can probably be grown commercially. Explorers, botanists, and others who have visited the islands since their discovery by Europeans in 1778 have been enthusiastic about this wild fruit. William Ellis,[2] who traveled over the island of Hawaii in 1823, observed the growth in six different places of this unusual raspberry and noted that native Hawaiians were growing the plant for its abundant production of luscious fruit.

Two distinct species of akala (*R. hawaiiensis* and *R. macræi*), as well as several related strains have been found growing at comparatively low elevations in the Hawaiian Islands.[3] During the past 100 years the plants have been destroyed to such an extent as now to exist only at the higher elevations in the forest reserves or other protected areas where they produce fruit of large size and fair quality during the summer. The fresh fruit is in strong demand locally, but on account of its perishable nature, the isolated position of the islands, and the high cost of transportation it can not be shipped in the fresh state from the mainland. With the development of an akala industry the fresh fruit could be used locally and the canned fruit for export trade.

During the year the horticulturist spent three days in the Hualalai forest reserve in North Kona, Hawaii, at elevations ranging from 4,500 to 6,000 feet, for the purpose of studying the *Rubus hawaiiensis*. In this forest the akala grows mostly as the underbrush of large trees, but it is sometimes also found in the open clearings. The plants vary from 6 to 10 feet in height. Some of the specimens observed were 15 feet high. The stems are perennial, 1 to 2 inches in diameter, strong, upright, and unarmed after the first or second year's growth. The branches that form the top are spreading and droop under the weight of the fruit which is borne on side spurs. The younger shoots are green or brown, and the entire bark is covered with soft green spines which are one-half to three-fourths inch in length. The leaves are pinnately 3-foliate, sparsely pubescent above and densely tomentose below, and the margins are sharply inciso-lobate and dentate. The plants bloom mainly in March and April and produce the fruit in June and July, but some fruit may be found at almost any time of the year. Two distinct variations of the fruit were found, in one instance the color of the mature fruit being dark purple, and in the other yellow. The dark-purple fruit predominates in the locality visited. The fruit averaged 1 inch in diameter, but

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[2] ELLIS, W. NARRATIVE OF A TOUR THROUGH HAWAII, OR, OWHYHEE; WITH OBSERVATIONS ON THE NATURAL HISTORY OF THE SANDWICH ISLANDS, AND REMARKS ON THE MANNERS, CUSTOMS, TRADITIONS, HISTORY, AND LANGUAGE OF THEIR INHABITANTS. Ed. 2, enl. 480 p. London. 1827.

[3] HILLEBRAND, W. THE FLORA OF THE HAWIIAN ISLANDS: A DESCRIPTION OF THEIR PHANEROGAMS AND VASCULAR CRYPTOGAMS. Annotated and published after author's death by W. F. Hillebrand. P. 116, illus. London, New York [etc.]. 1888.

larger specimens were common. (Figs. 6 and 7.) The fresh fruit is rather tart, but when served with cream and sugar it is delicious. Seeds of the purple type were brought to the central station in Honolulu and germinated, and the seedlings when of suitable size were

FIGURE 6.—Fruit and leaf of akala (*Rubus hawaiiensis*), a native species now under cultivation at the station

transferred to the Tantalus substation where the forest elevation approximates 1,000 feet.

Plants of 11 varieties of *Rubus* spp. have been successfully introduced from the experiment stations in Minnesota, Kansas, Iowa, and

Washington. Most of the plants are now under cultivation at the Tantalus substation.

MACADAMIA NUT

The Macadamia-nut tree has become well established in the Hawaiian Islands. It was first introduced from Australia about 1895

FIGURE 7.—Stem and fruiting branches of akala. Diameter of fruit 1½ to 2 inches

but did not attract much attention until a number of the seedlings came into bearing. The tree is now cultivated in many localities up to an elevation of about 2,500 feet and apparently is not exacting as to soil and moisture requirements. The high quality of the nut and

the general interest manifested in it have been sufficient reasons for making considerable investigations as to its possibilities.

For many years the station has been investigating the culture of this promising nut tree and has distributed large numbers of seedlings to numerous interested growers in the Territory. Owing to the natural variation of the species, it must be propagated by vegetative methods, particularly in places where the nut is to be grown commercially. In an experiment planned to cover a period of 10 years, cultural, varietal, and propagation studies of the Macadamia-nut tree are to be made. Experiments are to be conducted at the central station in Honolulu (150 feet elevation), the Tantalus substation (1,000 feet elevation), and at a proposed substation in Kona (2,000 feet elevation), Hawaii. These localities vary considerably in climate and soil, as well as in altitude.

At present the station has 800 Macadamia seedlings 8 months old as nursery stock, about 40 bearing trees of different ages at the Tantalus substation, and 12 grafted trees from the experiment made last year. Propagating material may also be obtained from cooperative experimenters working in different parts of the Territory.

REPORT OF THE CHEMICAL DIVISION

By J. C. Ripperton and C. Richter

EDIBLE-CANNA INVESTIGATIONS

STARCH PROPERTIES

Details of the method of determining the swelling power of edible-canna starch were worked out. Briefly, the method consists in gelatinizing the starch in a small Erlenmeyer flask by means of hot water delivered from a 100 c. c. pipette. The rolling motion produced in the flask by the hot water keeps the starch granules perfectly scattered while they are being subjected to a temperature which constantly rises until it reaches 80° C. The flask is then kept for 15 minutes at 80°. After 15 minutes the starch solution is poured into a graduated cylinder containing 190 c. c. of distilled water at room temperature, and the contents are thoroughly mixed by inverting the cylinder several times. The solution is then allowed to stand overnight. The starch granules have then settled with a sharp, well-defined boundary surface and a clear supernatant liquid. The volume of the swollen starch granules can be read in cubic centimeters. Since in no part of the entire process is the starch solution stirred or agitated, a large part of the starch exists as unbroken granules in the solution. By determining the swelling power, study is made of the properties of the swollen granules instead of an indefinite mixture of broken and ruptured granules as is usually done.

This method has given some interesting results with respect to the colloidal behavior of a starch solution. Among other things, it has been found that the swollen granule is negatively charged and as such is affected largely by cations. Anions have very little specific effect, but cations cause a reduction in the swell of the granule in proportion to their valence. By plotting the depression of the swell against concentration of cations, a curve is secured which is similar to the adsorption isotherm of a typical colloid.

It has been found that the swelling power of a starch can not be taken as an exact measure of its viscosity. Although for the large proportion of starches a high swelling power is associated with a high viscosity, and vice versa, there are numerous exceptions to the rule. These are being investigated to determine the cause.

In confirmation of the work of others, it was found possible to affect the viscosity and swelling power of a starch greatly by treating the raw starch at room temperatures with various salts and removing the excess salts by subsequent washing with distilled water. Again, the cations were the determining factors. The monovalent ions tended to increase the viscosity and swell, whereas the bivalent ions depressed the values. A number of starches were electrodialyzed and the amount of cations and anions received was determined.

One of the chief objects in beginning the study of the properties of starches was to determine the cause of the large differences in viscosity of edible-canna starches. These differences were found among commercial samples of other starches, but the cause is as yet unknown. The edible canna offers exceptional opportunities in this regard because its starch is susceptible to various factors. For example, the storage of rootstocks even for 48 hours causes a marked reduction in viscosity as compared with that of the starch prepared from the freshly dug rootstocks, and this reduction in viscosity continues with the length of storage. The results thus far indicate that loss of viscosity is an irreversible change, and that except for loss of swell and viscosity, these starches are similar in their reaction to the high viscosity of starches, for example, with respect to electrolyte.

In order to apply the methods developed in this study to better-known starches, comparative tests were made with a series of commercial potato starches. The results thus far indicate a decided similarity between the edible canna and potato starches. This is especially significant since commercial potato starch is at present largely imported and commands the highest price among the industrial starches.

SURVEY OF AREAS ADAPTED TO EDIBLE CANNA

To determine which of the canna-growing areas can be easily developed commercially, a survey was made of Waimea and Hamakua Upland, Hawaii; Kula, Hamakuapoko, and Hana, Maui; and the Kaneohe district, Oahu.

Waimea, Hawaii.—The Waimea district is known to be ideally adapted to the growth of edible canna. The climate is favorable on account of the high altitude, high humidity, and evenly distributed rainfall; the soil is loose, open, and of excellent fertility; and the topography is unusually flat. The yield of canna is very large. Although thousands of acres in this district are adapted to canna, very little of the area could be obtained in fee simple. The Waimea district is now largely devoted to grazing.

Hamakua Upland, Hawaii.—Hamakua Upland extends from Ahualoa to the Kaapahu homesteads. The rainfall of this region is much greater than at Waimea but is more seasonal, and the district is more likely to suffer from drought. The general topography is sufficiently smooth for cultivation, although toward Kaapahu it

is traversed by a number of deep gulches. The soils, particularly those of Ahualoa, are rather low in fertility and heavier in texture than are the soils of Waimea. Test plats of canna at Ahualoa gave fairly good yields. The region is mostly devoted to grazing.

Kula, Maui.—At Kula, test plantings of canna have done exceptionally well. The soil resembles that of Waimea and because of the cool temperature and lack of strong winds the region is desirable for canna growing. The rainfall is seasonal, however, with definite dry seasons. Lack of water would make it necessary to transport the rootstocks to lower levels for manufacture.

Hamakuapoko, Maui.—Hamakuapoko is copiously watered and has excellent soil. Plantings of canna at the Haleakala demonstration farm have done well. At present pineapples occupy nearly all the agricultural area. Should pineapple growing ever be abandoned in this region, edible-canna culture would offer possibilities.

Hana, Maui.—Hana has frequently been mentioned as offering possibilities for canna culture. The climate is undoubtedly desirable, the rainfall being copious and the humidity generally high. The rough topography and steep slope, however, would make it difficult and expensive to bring any large area under cultivation.

Kaneohe, Oahu.—At Kaneohe test plantings of canna have grown well. The rainfall is adequate and fairly well distributed. Kaneohe is close to sea level. The large number of cloudy days are of advantage in canna culture. Although the total area of the district is large, the topography is rather broken and would therefore necessitate planting in numerous small areas. This would appreciably increase the cost of production. Water is plentiful in Kaneohe for manufacturing purposes, and cost of trucking the starch to the Honolulu waterfront would be small.

EDIBLE CANNA IN ROTATION WITH PINEAPPLES

Working in cooperation with a local pineapple company, the station planted four ½-acre plats of edible canna on Oahu. The purpose of the planting was to determine the value of edible canna as a green manure in rotation with pineapples. If the canna proved to be resistant to the root-knot nematode of the pineapple, the top growth of the former might be used as a green manure in pineapple culture, and the rootstocks as a source of commercial starch. The results of the test were conflicting. At Waipio, where the soil was heavily infested with nematodes, the canna roots were appreciably affected, whereas at Pupukea, where there was another heavily infested area, canna showed practically no infestation. It is concluded, therefore, that edible canna should not be planted in a field immediately after a heavily infested pineapple ratoon has been plowed under, and that on soils not badly infested the canna can safely be used.

RANGE-GRASS NOTES

A number of ranches in the different islands were visited to determine the general nature of the range grasses growing thereon, particularly with respect to the introduced grasses. Herbarium specimens of different species were taken and subsequently identified. Samples of 28 grasses were collected and their nutritive constituents

determined. A number of samples of the new growth of the ekoa (*Leucæna glauca*) were also taken for analysis. It has often been contended that the ekoa is equivalent in feeding value to the pigeon pea. Results of analysis show, on a dry basis, that both the young leaves and immature pods have about the same feeding value as the pigeon pea (upper third of plant with seed in pod.)

COMPOSITION OF MACADAMIA NUTS FROM SEEDLINGS

Local plantings of the Macadamia nut are almost entirely seedlings. Nuts from different trees differ greatly in appearance, size, and thickness of shell. To determine whether these differences would also be accompanied by differences in chemical composition, seven samples were collected from individual trees growing in widely different localities. Determination of their nutritive constituents showed that of the two groups formed one was higher in oil and lower in sugars, and the other was lower in oil and higher in sugars. The other constituents were relatively constant. To determine to what extent maturity might account for these differences in composition, samples from a number of trees in the same locality were collected and the nuts in each sample divided into groups, depending on whether the outer hull of the nut was wholly green, part green, or entirely dry at the time the nut fell to the ground. The content of oil and sugars was found to vary within wide limits, depending on maturity. In the immature nuts the oil was low and the sugars were high, whereas the opposite was true in the mature nuts. Variations in composition among the trees tested were small. A method based on the specific gravity of the nut was worked out for use in separating the nuts of each tree into different grades of maturity. The groups of lighter specific gravity represented the immature nuts, and the group of greatest specific gravity represented the fully mature nuts. Only the latter should be used in analyses to compare the composition of nuts from different trees.

SURVEY OF THE SOILS OF THE KONA DISTRICT

A preliminary survey was made of the soils of the Kona district to determine the general nature of the soils, whether distinct types of soil and subsoil could be distinguished, and whether a general soil survey of the district would be feasible. The soils of Kona are relatively young. They are largely residual and are the result of the decomposition of lava flows which are mostly of the "a-a" type. In some places decomposition of the lava is at a more advanced stage than in others, the soil being deep and fine in texture. In general, however, decomposition is in the early stages; the soil is shallow, and the undecomposed lava is often apparent at the surface. It is a striking fact that the coffee trees make thrifty and vigorous growth on what appears to be practically undecomposed lava. The soil profile generally shows no pronounced difference in color or texture even in the deeper soils. Of the possible differences in soil types, there is a fine-textured type which previously was planted with sugarcane. The subsoil is pronouncedly yellow in color and heavy in texture. The most common type is loose in texture and black in color, merging gradually into a subsoil of the same texture

and of a dark-brown color. A possible third type is yellow in color and generally poor in fertility. It is said to be associated with a different type of lava.

Analyses were made of a series of 13 soil samples representing widely different parts of the district, and determination was made of their moisture, color, moisture equivalent, colloids, and pH. Although certain differences were noted between the various types, it is not believed that a general soil survey would give significant data. A study of the soils with relation to the different lava flows from which they are derived might be of value. Because of the fact that decomposition is yet in the early stages, and the roots of plants penetrate through the shallow soil into the lava itself, differences in the lava and its decomposition products probably bear a close relationship to the nature and fertility of the soil.

COLLOIDAL SOIL INVESTIGATIONS

A study of the colloidal fraction of the Hawaiian laterite soils was made for the purpose of comparing it with that of Temperate Zone soils. The chief difference, other than that of the origin, between tropical volcanic and Temperate Zone soils is due to weathering processes which have been brought about under warm, humid conditions with excessive leachings. As a result, tropical volcanic soils are high in the sesquioxides and proportionately lower in silica and the basic oxides and contain larger amounts of organic matter. The presence of manganese and titanium in larger amounts than usual in the soils of many localities is also characteristic of Hawaiian soils. It is thought that these differences will manifest themselves in the properties of the colloidal phase, especially in the adsorbing and base-exchanging properties.

During field trips to the various districts of the four principal islands, samples of 82 different soils were collected in sufficient quantities for physical and chemical determinations. The selection of these soil samples was based on differences in physical and chemical characteristics such as soil reaction, percentage of organic matter, mechanical analysis, water-holding and hygroscopic properties, color, geographical location, and origin. As to agricultural or nonagricultural districts, 35 soil samples were taken from sugarcane fields, 8 from pineapple fields, 5 from coffee plantations (Kona), 2 from edible-canna fields, 7 from diversified agricultural areas, and 25 from districts where only native vegetation existed or where the land is barren. According to the different islands, 7 soil samples came from Oahu, 40 from Hawaii, 25 from Maui, and 10 from Kauai. In each instance data were collected as to the topographical, climatological, and agricultural nature of the district. In many instances, the subsoils were also included. The soils were card indexed, classified, and tabulated according to soil class, mechanical analysis, percentage of colloids, and chemical properties. On the basis of this preliminary analysis, 21 soils were selected for the main part of the investigation. These soils vary widely as regards elevation, origin, appearances, and physical characteristics. Thirteen are from agricultural and eight are from nonagricultural areas.

Considerable time was devoted to a study of the methods of dispersion of soils used by other investigators. It is essential in making mechanical analysis to obtain as complete a dispersion of the soil particles as possible. It is not always possible to achieve this by purely mechanical means, that is, by shaking or stirring. The addition of chemical compounds is usually necessary to aid deflocculation.

Tests were made of the efficiency of various mechanical dispersing devices including the end-over-end shaker, electrical stirrer, and rubbing by hand in mortar, as well as the use of certain chemicals such as sodium and potassium hydroxide, ammonia, and sodium carbonate. The results obtained indicate clearly that (1) the electrical stirring device is far superior to the other means; (2) the destruction of the soil organic matter by means of hydrogen peroxide is unnecessary even in soils containing 10 to 12 per cent organic matter; (3) the washing out of the calcium before dispersion is desirable with numerous soils, but that twentieth normal hydrochloric acid solution is just as efficient for this purpose as fifth normal acid; (4) hot digestion is not necessary; and (5) the addition of the hydroxyl ions for the stabilization of the charge on the colloidal particles is most efficiently done in the form of sodium hydroxide or sodium carbonate. In some soil samples almost complete dispersion was obtained without the aid of chemicals. The foregoing results are in close agreement with those obtained by other investigators.

After a dispersion as nearly perfect as possible was obtained, the colloids in suspension were separated by sedimentation according to Stokes's law, being supercentrifuged at the rate of 35,000 revolutions per minute when all the colloidal particles except the so-called ultra clay were retained in the centrifuge. This latter fraction passed through the centrifuge and was separated from the solution by filtration through a Pasteur-Chamberland filter, the ultra clay being retained on the surface of the filter. The colloids obtained in the dry state were purified by means of electrodialysis, the cell described by Mattson being used for the purpose.[4]

In the soils tested thus far the ultra-clay fraction was surprisingly large, in some instances comprising over 1 per cent of the soil. This was appreciably more than the amount obtained in a similar manner from mainland soils.

The adsorbing properties of the isolated colloids were studied. The amount of water vapor adsorbed over 3.3 per cent sulphuric acid was determined both for soils and colloids. This value is an index to the amount of colloidal matter present. The figures thus obtained both in soils and colloids followed the hygroscopic coefficient curve, but the percentage of colloid calculated from them did not agree well with figures obtained by the hydrometer and pipette methods. Bouyoucos's hydrometer method has been used rather extensively for comparative purposes, both in this and other projects, and experiments are under way to determine to what degree this method indicates the actual percentages of colloids in Hawaiian soils.

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[4] MATTSON, S. ELECTRODIALYSIS OF THE COLLOIDAL SOIL MATERIAL AND THE EXCHANGEABLE BASES. Jour. Agr. Research 33: 553–567, illus. 1926.

MISCELLANEOUS NOTES

Specific-gravity determinations were made of the soils studied. These determinations were necessary in a study of the application of Stokes's law of settling particles, the velocity of settling being directly proportional to the specific gravity of the suspended particles. The specific gravity of the soils under examination was found to range from 2.19 to 3.36, depending on the amount of organic matter and sesquioxides present as determining factors. The highest (3.36) was a red clayey loam, while the lowest (2.19) was a black organic soil containing 18.5 per cent organic matter. Organic matter has a specific gravity of about 1.2 while that of the sesquioxides is about 5.3. The moisture equivalents as described by Briggs and McLane[5] was determined on a number of soils. These determinations were made on soils of the colloid study as well as on soils collected for other projects, such as the Kona coffee-land experiments. It is becoming customary to include this figure in soil-survey data as an index to water-holding capacity and to calculate the empirical "wilting coefficient" therefrom. The platted values run parallel with those of the hygroscopic coefficient and the moisture adsorbed in a saturated atmosphere.

An investigation was made to determine the causes of wilting of alfalfa in certain fields in the Koko Head region. Analyses of soil samples from these fields showed that they contained toxic accumulations of salt, presumably from the irrigation water, which contains as much as 75 grains of sodium chloride per gallon. The soil samples were examined for soil reaction (pH), soil colloids, total salts, sodium chloride, state of flocculation upon addition of water, the flocculating effect of various amounts of lime upon the puddled soils, and the presence or absence of soluble alkali carbonates.

REPORT OF THE AGRONOMY DIVISION

By H. L. Chung[6] and R. K. Lum

EDIBLE CANNA

The seven varieties of edible canna which were developed by the division three years ago have been grown continuously to determine their relative yield as compared with that of the original parent stock. In the last experiment these seedling varieties were grown on very sandy soils supplemented with commercial fertilizers. The results obtained indicated that soil which is very porous is not desirable for canna culture. Cultural tests were continued with the standard variety, No. 1039, from selected rootstocks grown on heavy soil. The yield obtained ranged from 18,798 to 24,891 pounds per acre.

CASSAVA

A cultural test with 14 varieties of cassava was begun December 3, 1926. After 28 months of growth the crop was harvested. Nine Blue Top plants made the heaviest yield, producing 413 pounds, or

[5] Briggs, L. J., and McLane, J. W. THE MOISTURE EQUIVALENTS OF SOILS. U. S. Dept. Agr., Bur. Soils Bul. 45, 23 p., illus. 1907.

[6] Transferred to extension service, University of Hawaii, June 30, 1929.

at the rate of 83 tons per acre. Other varieties produced from 8 to 49 tons per acre.

During the early part of 1927-28 the cassava plants bloomed profusely, and later produced seeds which matured and were planted. Observations on the seedling plants showed that many resembled the parent stock in color and pattern of leaves.

TARO

Both dry-land and wet-land varieties of taro were tested during the year. This test was begun primarily to determine the comparative yields of dry-land varieties selected from prolific stock; and of wet-land varieties grown on dry land, and to study the relative physical characteristics of the wet-land varieties.

Plantings were made of three varieties of Japanese dry-land taros taken from selected seed stock. On October 19, 1928, nine months after planting was done, the crop was harvested. Miyoko, No. 1886, gave the highest yield, producing at the rate of 20,473 pounds per acre, and was followed by Ahkado, No. 1883, with 18,738 pounds, and Trunoko, No. 1884, with 18,658 pounds. A similar planting of these varieties was made on September 18, 1928. On June 8, 1929, the crop was harvested. Miyoko again led with 13,310 pounds to the acre, and was followed by Trunoko with 11,374 pounds, and Ahkado with 11,132 pounds per acre.

In connection with this experiment, a cultural test with the three Japanese varieties was made to determine the value of corm and top for planting material. The results indicated that the top is the better planting material so far as yield is concerned.

Sixteen varieties of wet-land taro were tested. The four highest yields were produced by Oapu with 38,115 pounds per acre, Lehua and Kalalau each with 30,492 pounds, and Piko Uliuli with 28,858 pounds. Of the 10 Hawaiian dry-land varieties tested, Iaia gave the highest yield, 9,196 pounds, and was followed by Mana Eleele with 8,228 pounds, and Kai with 7,260 pounds.

In connection with the cultural tests of the dry-land and wet-land varieties of taro, a study was made of the proportions of top, corm, and fibrous roots of a taro plant as it was harvested. The average of all the dry-land varieties studied showed 31.7 per cent top, 54.7 per cent corm, and 14.8 per cent fibrous roots; and for the wet-land varieties, 52.2 per cent top, 34.1 per cent corm, and 13.6 per cent fibrous roots.

KUDZA

Kudzu (*Pueraria thunbergiana*) was cultivated for use as a forage and root crop. The planting yielded at the rate of 34 tons of roots per acre. Individual hills yielded 47 pounds of roots.

Kudzu is used primarily as an edible root crop by the orientals in Hawaii. However, in Hawaii and in Maui this legume finds a place as a forage crop on grazing lands.

GINGER

Two crops of Chinese and other gingers were grown with promising results.

SWEETPOTATOES

One hundred and thirty standard sweetpotato varieties and seedlings were grown during the year. Some of the seedlings produced seeds which matured. These are to be planted to permit a study of the variations in succeeding seedlings. Sweetpotato seeds from the above-mentioned source were distributed to various local agricultural institutions requesting them.

In cultural tests with other standard sweetpotato varieties, the yield ranged from 1,400 pounds to 9,095 pounds per acre, the latter yield being obtained from the Tantalus substation.

CORN

During the year new varieties of corn were tested, and an attempt was made to improve the size and shape of the Cuban Red corn kernels, and to segregate the white and the red cob characteristics in the yellow Guam corn.

A yellow dent corn from F. G. Krauss was grown at the station with very good results. The seed corn was obtained from the Parker ranch by Doctor Krauss, who requested that the variety be tried particularly under lowland conditions. The crop grown at the station is beginning to mature.

The local market demands a corn of golden color and small-sized kernels, and for this reason an attempt is being made to establish such a strain by selection. A yellow variety of Guam corn was developed by the station in 1920. Since then a variation has been noted in the color of the cobs, and efforts have been made to segregate two strains on the basis of cob color.

FORAGE GRASSES

During the past two years Mexican grass (*Exophorus unisetus*) has been vegetatively selected from heavy-stooling clumps. One outstanding planting included 16 rows, each of which occupied an area of 336 square feet, the plants being set 4 feet apart in the row. The yields of green feed obtained 67 days after the crop was planted were rather uniform, the lowest being 4,018.9 pounds per acre, and the highest 6,935.9 pounds, with an average of 5,397.8 pounds. Immediately after the harvest the area was treated with both organic and inorganic fertilizers. After 30 days the growth was harvested. The data obtained indicated that the areas receiving nitrate of soda, superphosphate (acid phosphate), and muriate of potash in combination yielded at the rate of 24,113 to 26,447 pounds per acre. This fertilizer experiment was continued until April 24, 1929, when the last harvest was made and yields were recorded.

Results of fertilizer tests with Napier grass (*Pennisetum purpureum*) and Merker grass (*P. merkeri*) indicated that the plats receiving nitrate of soda at the rate of 450 pounds per acre gave the best results.

Napier-grass cuttings are frequently held until the field has been prepared for planting. An experiment was made to determine the length of life of Napier grass. Propagating material which was piled in a heap and exposed to the weather was found to make 100 per cent growth 29 days after cutting. After the twenty-ninth day,

however, deterioration was rapid. Napier-cane cuttings when piled in a heap in a shed showed a 60 per cent growth 65 days after cutting. However, no growth was obtained from a lot similarly protected from the sun 74 days after cutting.

Kikuyu grass (*P. clandestinum*) is very promising. The plant establishes itself readily on new ground by means of its runners, and attains an average height of 3 feet. The division was unable to comply with all the requests from stockmen and farmers for this grass to establish new pasture areas.

Plats demonstrating range grasses were again maintained for the benefit of those who are interested in them.

ORIENTAL-VEGETABLE CULTURE

Studies of oriental-vegetable culture were confined to aquatic species, including the lotus root (*Nelumbium nelumbo*), arrowhead (*Sagittaria sagittifolia*), and Jesuits' nut (*Trapa natans*).

GREEN-MANURING CROPS

The hyacinth-bean (*Dolichos lablab*) and the Mauritius bean were cultivated during the year to determine their adaptability as green-manuring crops. Both made heavy vegetative growth. The *D. lablab* produced 18 tons of green matter per acre four months after planting and the Mauritius beans yielded a similar amount for the same period.

RICE LANDS

Largely on account of the inroads made by the rice borer (*Chilo simplex*) during the past two years, more than 80 per cent of the rice-growing lands are now being abandoned. Landowners and lessees are anxious to know how these rice lands may best be used. In some places where the soil is loose, vegetables and flowers may be grown to advantage provided that the cost of transporting them to market is not too high. This land may be leased for such purposes at an attractive rental. On the heavy-soil type the growing of soiling crops may be possible, or grasses for grazing purposes may be planted. Those who are horticulturally inclined may find it to their advantage to furrow the land deeply and then establish a litchi-fruit orchard on the ridges. The furrows would make it possible to keep water on both sides of the ridge so that an abundance of moisture would be available for the trees at all times. This method of planting is similar to that used in the litchi orchards of southern China.

LETTUCE BREEDING

The agronomy division has been endeavoring for five years to develop a strain of lettuce that will head satisfactorily in the Hawaiian Islands. It has been necessary in the past to grow the head-lettuce plants at an altitude of 1,000 feet or more. Heat seems to stimulate the growth of the internodes and thus inhibits the tendency to head. The experiment started with 14 standard varieties to determine their reactions to local environment. The seven most promising varieties were used in hybridization work which is still under way in an attempt to fix a desirable type of solid-headed lettuce.

POULTRY

During the time that could be spared from agronomic work the agronomist again assisted poultrymen with problems in connection with the poultry industry. Poultry diseases and methods of controlling them received much attention. Articles of interest to poultrymen were submitted to the local press until December, 1928. In October and again during the early part of December the agronomist assisted with the Kauai poultry and pigeon show.

REPORT OF THE HALEAKALA SUBSTATION

By H. F. Willey

At the Haleakala substation 30 rods of new fence were constructed and 56 rods of old fence rebuilt. Most of the fence posts were obtained from eucalyptus trees which were planted at the substation in 1922. Clearing of the gulch land was continued for additional plantings of coffee, fruit, and nut trees, grapes, and berries. Three-hundred and fifty trees had already been set out. Approximately 188 varieties of 60 different species of crops were under test, including pigeon peas, edible canna, cassava, dry-land taro, sweetpotatoes, forage and pasture grasses, and many varieties of peppers, tomatoes, grapes, watermelons, muskmelons, and other fruits and vegetables. Distribution of planting material of all the improved strains under test was continued as in past years. Distributions were made of more than 100 pounds of improved field seeds, 185 pounds of edible-canna tubers, 2,000 sweetpotato plants, 500 strawberry plants, 300 pounds of taro tubers, and twelve 1½-ton truck loads of Napier and Merker grass cuttings. The substation has 1 registered Holstein bull, 2 mules, 3 cows, 1 heifer, 3 calves, 1 hog, 1 saddle pony, 1 filly, about 40 chickens, and nearly a dozen rabbits.

Experiments were made with pineapples to determine the effect on yield of using different cover and green-manure crops with and without fertilizer. The average weight of the pineapples was 3.71 pounds following lupines, 3.37 pounds following edible canna, 3.48 pounds following jack beans, and 3.59 pounds following sweetpotatoes. The plat receiving sulphate of ammonia at the rate of 250 pounds per acre produced fruits averaging 3.72 pounds, whereas the unfertilized plats produced fruits averaging 3.02 pounds. Other experimental plantings of pineapples totaling several thousand plants have been made, but none of the crops have as yet matured. There are at present 10,626 pineapple plants growing at the substation and 1,400 aditional plants have been put out with a private cooperator at an elevation of approximately 3,300 feet. (Fig. 8.)

The superintendent continued to give considerable attention to agricultural extension work. In this connection he traveled about 3,400 miles between July 1 and December 31, 1928. At this time he was placed on part-time basis with the newly reorganized agricultural extension service of the University of Hawaii. He also made numerous trips to various parts of the island to assist homesteaders and others in the culture of diversified crops and gave advice and demonstrations in poultry culling and in artificial incubation. He also gave demonstrations in spraying various crops re-

quiring such treatment. In connection with the 4–H club work, 11 boys' and girls' 4–H clubs were organized with a total membership of 116. (Fig. 9.) The farm club work included gardening clubs,

FIGURE 8.—Cooperative experiment with pineapples, Maui (3,300 feet elevation). Plants mulched with paper to conserve heat and moisture. Altitude is about 2,000 feet above the customary maximum for pineapple production in the Hawaiian Islands

poultry clubs, pigeon clubs, rabbit clubs, and pig clubs. During the year the superintendent took charge of the first boys' and girls' 4–H club camp ever held in the Territory of Hawaii. This camp was held at the Haleakala substation May 24 and 25, 1929. Twelve of the

FIGURE 9.—Peppy Girls' 4–H Sewing Club. Director W. A. Lloyd and Club Leader Mrs. E. A. Willey, standing. Haleakala substation

14 clubs operating on Maui were represented at the camp. Koichi Ito of Hamakuapoko, Maui, a club member, was sent as a delegate to the National Boys' and Girls' 4–H Club camp at Washington, D. C., during the summer of 1929.

Commencing January 1, 1929, the superintendent was placed on half-time basis with the agricultural extension division of the University of Hawaii, cooperating with the United States Department of Agriculture. The station, however, continued to finance a portion of the extension activities of the superintendent until June 30, 1929, at which time he again assumed full-time activities there.

REPORT OF EXTENSION AND DEMONSTRATION WORK

By R. A. Goff

The extension agent served with the extension division of the station from July 1, 1928, to December 31, 1929, when he was transferred on full-time basis to the extension division of the University of Hawaii, cooperating with the United States Department of Agriculture. During his six months with the station he continued to act as general county agent for the island of Hawaii and to visit farmers for the purpose of advising them regarding crop rotations, feeding problems, and orchard planning and culture. He also spent considerable time in arranging for range-grass demonstrations. These were based on observations made in previous years at the cooperative grass plantings on the Parker ranch and elsewhere. Specimens of the more important grasses were obtained for botanical study and chemical analysis.

REPORT OF BOYS' AND GIRLS' CLUB WORK

By Mabel Greene

Incident to the changes in the administration and organization of the agricultural extension work, the club activities were confined to the rural districts of the island of Oahu. The work was enlarged to include women's club work as well as girls' club work. The boys' club work was directed by a representative of the University of Hawaii. The women's and girls' club work included clothing and food preservation and utilization. Attention was also given to home improvement, and instruction and assistance were given in making such house furnishings as curtains, table covers, pillowcases, sheets, bedspreads, towels, and children's clothes. An attempt was made during the first six months of the year to correlate this work as closely as possible with the new lines of extension activities at the University of Hawaii in cooperation with the United States Department of Agriculture. On January 1, 1929, the boys' and girls' club work was transferred to the University of Hawaii.

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HAWAII AGRICULTURAL EXPERIMENT STATION
HONOLULU, HAWAII

Under the joint supervision of the
UNITED STATES DEPARTMENT OF AGRICULTURE
AND THE UNIVERSITY OF HAWAII

Washington, D. C. June, 1931

REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION, 1930

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CONSOLIDATION OF STATION WORK IN HAWAII

Beginning July 1, 1929, the agricultural activities of the Federal experiment station and of the University of Hawaii were brought formally under the joint control of the United States Department of Agriculture and the university, in accordance with the following memorandum of understanding, approved by the Secretary of Agriculture and the President of the University:

MEMORANDUM OF UNDERSTANDING

Whereas, The University of Hawaii may under the Act of Congress approved May 16, 1928, receive funds appropriated by Congress for conducting experiments in agriculture; and

Whereas, The Department of Agriculture is now maintaining an agricultural experiment station in Hawaii under appropriations made by Congress; and

Whereas, The said Act of May 16, 1928, specifically provides "That the experiment station so established shall be conducted jointly and in collaboration with the existing Federal experiment station in Hawaii in enlarging and expanding the work of the said Federal experiment station on cooperative plans approved

by the Secretary of Agriculture; and the Secretary of Agriculture shall coordinate the work of the Territorial station with that of the Federal experiment station and of the United States Department of Agriculture in the Islands":

Therefore, With a view to securing economy and efficiency in the conduct of the experiment station work in the Territory of Hawaii, the Secretary of Agriculture of the United States and the President of the University of Hawaii, with the approval of the Board of Regents of said university, hereby make the following memorandum of understanding with reference to the relations between the University of Hawaii and the United States Department of Agriculture for the organization and conduct of experiment station work in agriculture in the Territory of Hawaii:

I. The University of Hawaii agrees:

(a) That instead of establishing a separate and independent station it will carry on its experimental work in association with that of the existing Federal experiment station, the joint enterprise hereafter to be known as the Hawaii Agricultural Experiment Station, conducted jointly by the United States Department of Agriculture and the University of Hawaii;

(b) That the property, equipment, and all appurtenances of the present Federal experiment station as well as that hereafter acquired by reason of appropriations made by the Congress to the Department of Agriculture for the support of said station shall be and remain the property of said Department of Agriculture;

(c) That the funds received hereafter by the University of Hawaii for experiment station work from the Congress or any other source will be expended by said university for work carried on through said Hawaii Agricultural Experiment Station;

(d) That it will cooperate with the Department of Agriculture in such agricultural experiment station work as the department is or may be authorized to conduct in the Territory of Hawaii.

II. The United States Department of Agriculture agrees:

(a) To maintain an Office of Experiment Stations which shall represent the department in its relations with the Hawaii Agricultural Experiment Station and shall have charge of the department's business connected with the administration of all funds provided by Congress for said station;

(b) That it will conduct in cooperation with the University of Hawaii through the Hawaii Agricultural Experiment Station all experimental work in agriculture which it is or may be authorized to conduct in the Territory of Hawaii;

(c) That all property, equipment, or appurtenances, purchased through funds appropriated by Congress directly to the Territory under the Act of May 16, 1928, or property, equipment, and all appurtenances acquired in any other manner shall remain the property of the University of Hawaii;

(d) That such members of the staff of the University of Hawaii as may be detailed to experiment station work may be commissioned as agents or collaborators of the United States Department of Agriculture, enabling the use of the departmental franking privilege in conducting official business.

III. The University of Hawaii and the United States Department of Agriculture mutually agree:

(a) That, subject to the approval of the President of the University of Hawaii and the Secretary of Agriculture, or their duly appointed representatives, the agricultural experiment station work shall be planned under the supervision of the director of the Hawaii experiment station, and that the approved plans shall be executed by the director of said agricultural experiment station;

(b) That all agents appointed for experiment station work by the University of Hawaii under this memorandum shall be joint representatives of the University of Hawaii and the United States Department of Agriculture, and the cooperation shall be plainly set forth in all publications or other printed matter issued and used in connection with said agricultural experiment station work by either the University of Hawaii or the United States Department of Agriculture;

(c) That the plans for the use of all congressional funds appropriated for experiment station work shall be made by the director of the Hawaii experiment station subject to the approval of the Secretary of Agriculture and the President of the University or their designated representatives, and when so approved shall be executed by the director of the station;

(d) That the headquarters of the Hawaii Agricultural Experiment Station shall be, for the present, at the present site of the Federal experiment station on Pensacola Street, but station work may be conducted at said site or on the university farm or elsewhere if the director of said station acting with the approval of the Secretary of Agriculture and President of the University, or their representatives, shall so decide.

(e) That until otherwise agreed the director of the Hawaii Agricultural Experiment Station shall be the present director of the Federal experiment station, and any succeeding director shall be chosen by the Secretary of Agriculture and the President of the University acting jointly.

IV. This memorandum shall be in effect when approved by the President of the University of Hawaii and the Secretary of Agriculture of the United States and it shall remain in effect until expressly abrogated by either of the signers or his successor in office, or amended by mutual agreement of both.

The enlarged experiment station is known as the Hawaii Agricultural Experiment Station, and is under the immediate management of the former director of the Federal station. The Federal experiment station was operated as an independent local institution from its establishment in 1901 to June 30, 1929, and agricultural investigational work at the College of Agriculture of the University of Hawaii began in 1908. The property of the two coordinated institutions is to be kept separate, but there has been a pooling of interests, personnel, and facilities, with an increase in efficiency and economy of administration and more effective cooperation with other local institutions also engaged in similar experimental work.

Under the Act of Congress, above referred to, extending the benefits of the Hatch, Adams, and Purnell Acts to Hawaii, the station received $15,000 during the year ended June 30, 1930. Beginning with the fiscal year 1931, it is to receive certain annual increments until the maximum of $90,000 provided by the three acts is reached in the fiscal year 1941.

SUMMARY OF INVESTIGATIONS

By J. M. Westgate, *Director*

Selective breeding work with over 600 different lots of pigeon peas and determination of the effect of different spacings on seed production with 85 lots of green-manuring crops constituted the chief activities of the agronomy division. Rows and plats of the more promising forage grasses were maintained for yield tests and also to furnish a convenient supply of planting material for local distribution, especially to dairy farmers. Tests of many varieties of taro, sweetpotato, edible canna, and cassava were made. The more promising of the lettuce hybrids produced by the station were planted for further elimination and selection. Numerous miscellaneous field crops and vegetables were under trial.

At the Haleakala substation, the university farm, and the Pensacola Street station similar plantings were made of pigeon peas for breeding and of green-manuring crops for seed production. Be-

cause of the higher altitude at the Haleakala substation markedly different results in growth were noted in almost every instance. Approximately 245 varieties, representing 100 different species of crops, were under trial at this substation, and improved planting material was distributed to many interested persons. The Waikea substation, Hawaii, was maintained on a self-supporting basis to determine the cost of growing sugarcane on a 62-acre area of land in the Waikea homestead tract. The Kona substation, Hawaii, was established, and preliminary cooperative experiments were undertaken, pending the erection of suitable buildings and the clearing of the land for experimental plantings.

Work in animal husbandry begun by the university was largely along the line of feeding experiments. The sixth year of a proposed 7-year test, undertaken to determine the effect of feeding molasses to dairy cows, was completed, and a test to learn the effect of feeding sprouted oats to breeding dairy cows and brood sows was extended.

The chemical division covered a rather wide range of activities, including studies of edible-canna starch and the Macadamia nut, a preliminary coffee-soil survey in Kona, Hawaii, and a study to determine the most practicable method of rejuvenating a 30-year-old coffee plantation. Attention was also given to a study of soil colloids and to the development of suitable commercial methods of preserving and utilizing the avocado. As a result of the latter study it is hoped to obtain a preserved product that can be shipped. Present quarantine regulations prohibit the shipment of the fruit in the fresh state.

The nutrition laboratory of the home economics division was transferred during the year to a substantial new wooden building occupying a floor area of 1,700 square feet. Colonies of guinea pigs were bred for use in investigations comparing the vitamin content of Hawaii and mainland grown oranges and tomatoes. Colonies of white rats were bred for use in a study of the biological value of the protein of the pigeon pea and the food value of Chinese cabbage.

The horticultural work was primarily concerned with investigations relating to coffee culture and the establishment of improved varieties of fruits and nuts in the Hawaiian Islands. The coffee investigations included the accumulation of propagating material of different species and varieties, growing seedlings to permit study of vegetative methods of propagating desirable varieties, and further studies on the cultural and pruning requirements of the tree. Numerous problems in connection with the Macadamia-nut industry were attacked. This industry is being substantially developed on several plantations and by individuals, including James H. Pauls and Ralph Moltzau, both of one of the Macadamia-nut plantations, who have successfully mastered the technic of grafting the Macadamia and have been instrumental in establishing a large commercial Macadamia-nut orchard. Investigations were continued with the large native raspberry, known locally as the akala (*Rubus hawaiiensis* and *R. macraei*). Propagating and laboratory material was collected, and the native and the best varieties from the mainland of the United States were compared. Cultural experiments at the Tantalus substation and cooperative experiments at different elevations on the island of Hawaii were begun with the akala during the

year. The citrus orchard now contains oranges (12 varieties), lemons (5 varieties), pomelos (14 varieties), limes (4 varieties), mandarins (5 varieties), and citrus hybrids (12 miscellaneous kinds). Sixty-two newly introduced fruit and nut plants were under trial.

The poultry division continued its efforts to discover a simple method for determining the sex of purebred day-old chicks, and to learn how sorehead or fowl pox is ordinarily transmitted to young chicks. Mosquitoes were found to be the principal agents transmitting sorehead to baby chicks, and the trouble was effectively overcome by screening the runs. Experiments were made to compare the feeding value for poultry of Hawaii coral and imported oyster shells. The relative merits of the "all mash" and "mash-and-scratch" methods of feeding laying hens were determined.

The soil physics division studied the factors affecting the rate and magnitude of capillary rise of water and its movement through colloidal soils when supported over a free-water table. The most important conclusion reached thus far is that capillary rise of water through sands is not a simple continuous process, but the result of two actions each of which follows a different law. The exact nature of these laws has not yet been determined.

REPORT OF THE AGRONOMY DIVISION

By J. M. Westgate and M. Takahashi

PIGEON PEAS

Numerous former plantings of pigeon peas were maintained throughout the year, and 585 hybrids were planted at the university farm, the Pensacola Street station, and the Haleakala substation. These three localities represent material differences in soil, altitude, and moisture conditions. Ten hills each of different selections were planted as a rule.

As a basis for comparison, plantings were made of the standard well-fixed strain D, which is a selection from the original plant No. 218 obtained from Porto Rico and first grown at the station in 1906. Strain D was planted in every third or fifth row, depending upon the uniformity of the soil.

The seed of early-maturing selections, planted in December, 1929, and in January, 1930, ripened June 30, 1930. An attempt is being made to develop a general-purpose type of pigeon pea (1) of medium vigor, reasonably heavy seeding habits, and fair foliage production for use as forage, green manure, and for general seed-production purposes (fig. 1); (2) of satisfactory seed and forage-production habits which will be adapted to the higher lands (3,000 to 5,000 feet in elevation); and (3) of culinary value with flavor of sufficient mildness to enable the crop to compete successfully on the market with the garden pea.

GREEN-MANURING CROPS

About 85 lots of green-manuring crops aggregating approximately 50 species, were planted on the experimental plats of the university farm, the Pensacola Street station, and the Haleakala substation.

With a few exceptions, the plants of each lot were set 6, 12, 24, and 36 inches apart in rows 5 feet apart, to learn the effect of the different spacings on yield of seed. A few standard varieties were spaced uniformly in long rows, and various sections of the rows were cut back at different heights to determine the effect on seed production. The crops that made the best growth at the lower altitudes were, in the order named, the Mauritius velvetbean (fig. 2), the pigeon pea, the jack bean, fuzzy rattle pod (*Crotalaria anagyroides*), rattle pod (*C. incana*), *C. saltiana*, sunn hemp (*C. juncea*), papapa bean (*Dolichos lablab*) (fig. 3), pega-pega (*Desmodium cajanifolium*), and *Meibomia rensonii*. At the Haleakala substation where the elevation is 2,160 feet, the blue lupine and the pigeon pea

FIGURE 1.—Experimental pigeon-pea plantings, University of Hawaii

were more satisfactorily grown. None of the green-manuring crops at the higher elevations bore satisfactorily, apparently because of the cold, wet weather prevailing at the time the plants were growing. Most of the same kind of plants at the lower elevations (50 to 100 feet) produced excellent crops of seed.

FORAGE GRASSES

Plantings of the more promising forage and soiling grasses were maintained at the university farm, the Pensacola Street station, and the Haleakala substation. At each place the plantings formed a convenient source of propagating material for distribution to dairymen and others desiring to grow one or more of the available species. The more popular grasses are the Mexican grass (*Exophorus unisetus*), Napier grass (*Pennisetum purpureum*), Merker grass (*P. merkerii*), kikuyu grass (*P. clandestinum*), and Rhodes grass (*Chloris gayana*).

ROOT CROPS

Various root crops were grown at the three principal branches of the station. Some 16 varieties of wet-land taro were grown at the

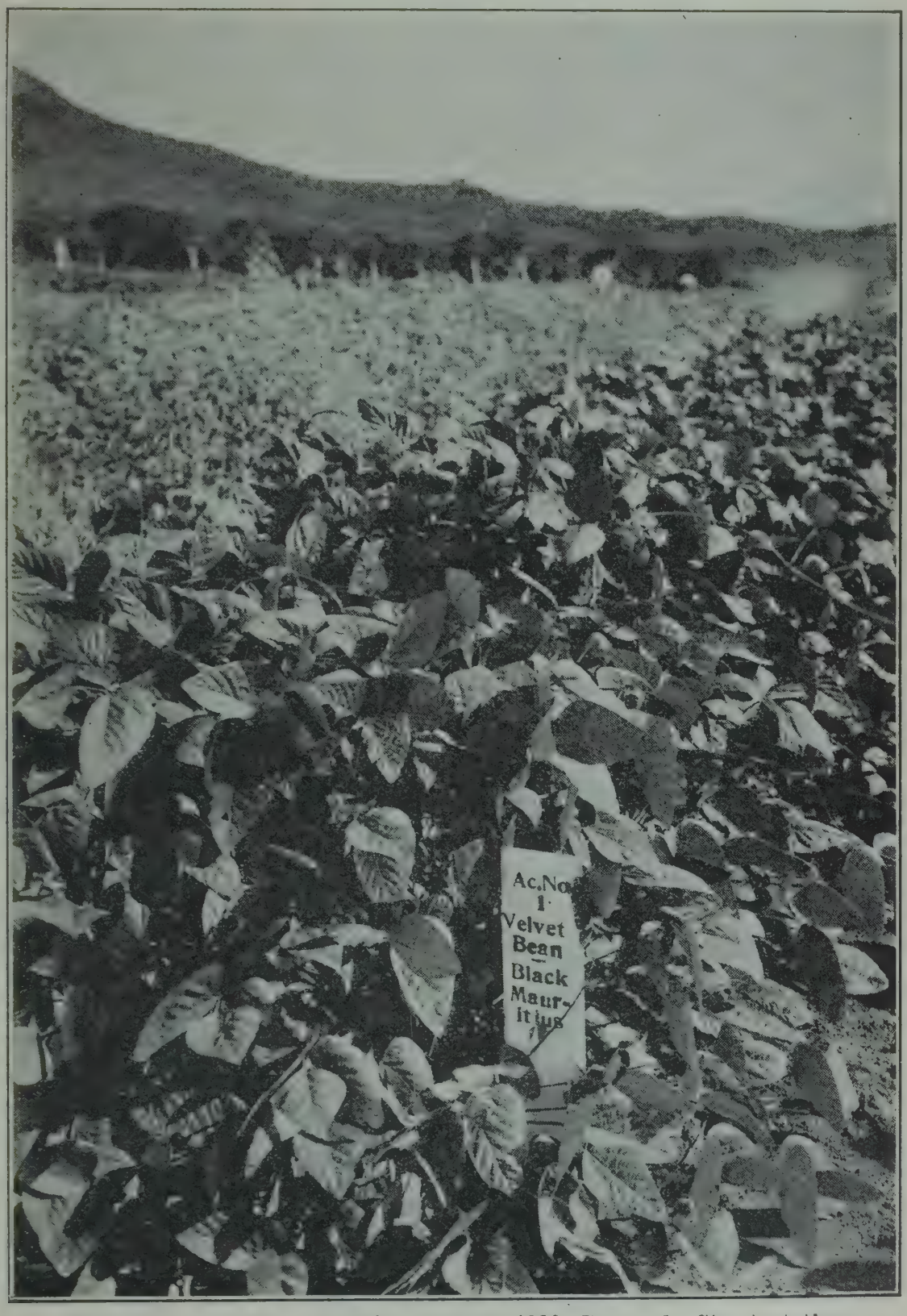

FIGURE 2.—Mauritius velvetbeans, May, 1930, Pensacola Street station

university farm, where there is ample water for irrigation. About 29 varieties of dry-land, wet-land, and Japanese taro, over 60 varieties of sweetpotatoes, and several strains of edible canna and cassava

were under test at the Pensacola Street station. Dry-land taro and edible-canna plantings were maintained at the Haleakala substation, where they serve as a source of propagating material for those desiring to make experimental plantings of the crops.

FIGURE 3.—*Dolichos lablab* as a green-manuring crop, May, 1930, Pensacola Street station

LETTUCE BREEDING

Experiments to develop lettuce plants which will head satisfactorily at low altitudes in the Tropics, begun a number of years ago at the

Pensacola Street station, are still in progress, and some of the outstanding hybrids are now being tested. (Fig. 4.) Two of the hybrids are segregating very badly, and two plants, presumably hybrids, appear to be stable, notwithstanding the fact that hybrids seemingly can not be stabilized in the first two or three generations. However, regardless of whether these two plants are hybrids, they seem to be the most promising of the lot under test. An attempt is also being made to select from the segregating hybrids several good types of leaf lettuce for use in table garnishing.

MISCELLANEOUS NOTES

Owing to the impracticability of obtaining an agronomist during the year, the station merely maintained various miscellaneous plantings at the Pensacola Street station and recorded routine data regarding them. These crops included several varieties each of corn, beans, tobacco, chili peppers, alfalfa, and sweetclover.

FIGURE 4.—Lettuce-breeding plats, June, 1930, Pensacola Street station

REPORT OF THE HALEAKALA SUBSTATION

By H. F. WILLEY

At the Haleakala substation some 1,400 feet of fence was shifted in a readjustment of the fields and pasture areas. Approximately 300 feet of piping was laid for the purpose of extending the water system. A temporary wooden building, 14 by 20 feet, was built for use as a seed house. About 245 varieties of 100 different species of vegetables, fruits, and field crops were under test, including dry-land taro and sweetpotatoes (13 varieties of each), tomatoes (15 varieties), grapes (16 varieties), field corn and pop corn (7 varieties), watermelons (12 varieties), muskmelons (16 varieties), and 85 lots of green-manuring crops representing approximately 52 species. Distributions of improved planting material included 2,500 cuttings of sweetpotatoes, 3,000 cuttings of Uba cane, twenty 1½-ton truck

loads of Napier and Merker grass cuttings, 250 pounds of edible-canna tubers, 400 strawberry plants, 20 banana plants, 5 avocado seedlings, and 4,500 pineapple plants. The eucalyptus trees that were planted at the substation many years ago have grown remarkably well and in addition to making effective windbreaks supplied all the fence posts needed at the station during the year.

Extension work on the island of Maui was taken over by the extension division at the beginning of the year. This change enabled the superintendent to devote his entire time to substation work. The principal activities of the substation included testing approximately 600 selections and hybrids of pigeon peas (*Cajanus indicus*); growing 85 lots of green-manuring crops (fig. 5) representing 52 different species set different distances apart in the rows to determine the effect of spacing on seed production; testing various green-manuring crops for pineapples; determining the relative merits of pineapple

FIGURE 5.—Green-manuring crop tests, Haleakala substation. Lupines at left; *Dolichos lablab* at right

shoots, slips, and crowns for use as planting stock; and studying the effect of various rates and kinds of fertilizer application on size and total yield of pineapples. The cooperative pineapple plantings near Olinda, at an elevation of 3,300 feet, were continued to determine the possibility of extending the commercial culture of the crop to that elevation.

REPORT OF THE WAIAKEA SUBSTATION

By R. K. PAHAU

The work of the Waiakea substation was largely a continuation of studies of the cost of producing sugarcane, but a small dairy herd and a piggery were maintained. The Waiakea substation was established July 1, 1921, and will be formally closed August 31, 1930. The original purpose of the station was to carry on both experimental and demonstration work with sugarcane and to a lesser extent with diversified crops and with livestock. The station has been operated

as a demonstration sugarcane-growing homestead since 1925 rather than as an experiment station, and an exact account of the cost of raising and delivering the cane to the mill has been kept since that time. Beginning July 1, 1927, the station has been operated on a self-supporting basis, the receipts from the sale of the sugarcane being used for operating purposes. Cost-production figures, kept over a period of 10 years and on file at the University of Hawaii, should be of interest to those who are concerned in sugarcane homesteading in Hawaii. These data give definite information as to the actual cost of growing sugarcane on a 62-acre tract under the conditions at Waiakea.

REPORT OF THE KONA SUBSTATION

By R. K. Pahau

The Territorial Legislature in 1929 appropriated $5,000 for the establishment of a substation in the Kona district, Hawaii. Several inspection trips had to be made before a suitable location could be found and title to the land was not obtained until April 8, 1930. The award of contract for building the superintendent's residence and for installing a suitable water system was made June 3, 1930, at a total cost of $4,440. The 3-acre area of land on which the substation is located will be used as a working center from which various lines of experimentation can be operated throughout the region. Cooperative experiments, begun with suitably located persons during the year, included studies in representative coffee plantation to increase yield and develop improved strains; pollination studies with coffee flowers; studies of the relative merits of any one coffee plant with those of two of the same kind of plants in a place system; tests and selections of Hawaii raspberries (akala berries); and further tests and observations on the Macadamia-nut tree, the avocado, and various species of citrus and coffee. With the establishment of a substation at Kona it is possible to prosecute the present lines of work more effectively than would have been the case under the old conditions.

REPORT OF THE ANIMAL HUSBANDRY DIVISION

By M. Maneki

CATTLE

The head of the animal husbandry division was absent from the station on sabbatical leave and exchange arrangements for the entire year, but the work as previously developed by him was successfully carried on in his absence. The dairy of the university is maintained in a dual capacity. It furnishes a functioning herd for instructional purposes at the university and also animals for use in experiments made by the Federal experiment station. The dairy herd now numbers approximately 60 animals of different ages, and an attempt is being made to keep about 30 of the cows in milk throughout the year. (Fig. 6.) The experiment begun by the university to determine the effect on cows of feeding them a ration containing 25 per

cent of sugarcane molasses was continued. This experiment is now at the end of its sixth year and will probably be carried on for another year. All the cows not otherwise under special test are receiving the ration. During the year six representative cows were used as a special control group to permit study of their behavior prior to placing them on the molasses ration. Twenty-four cows are receiving the molasses ration, while the six cows in the control group are being fed a ration in which the molasses has been replaced by grain concentrates in the proper proportions.

The animals are weighed on or near the fifteenth of each month. Notes are being kept of the milk flow and breeding ability of the adults, and of the general health of the offspring. Fat tests of the milk are made once a month, the samples being taken from four consecutive milkings of each cow. Individual milk weights are taken at each milking, and the daily feed consumption of each cow

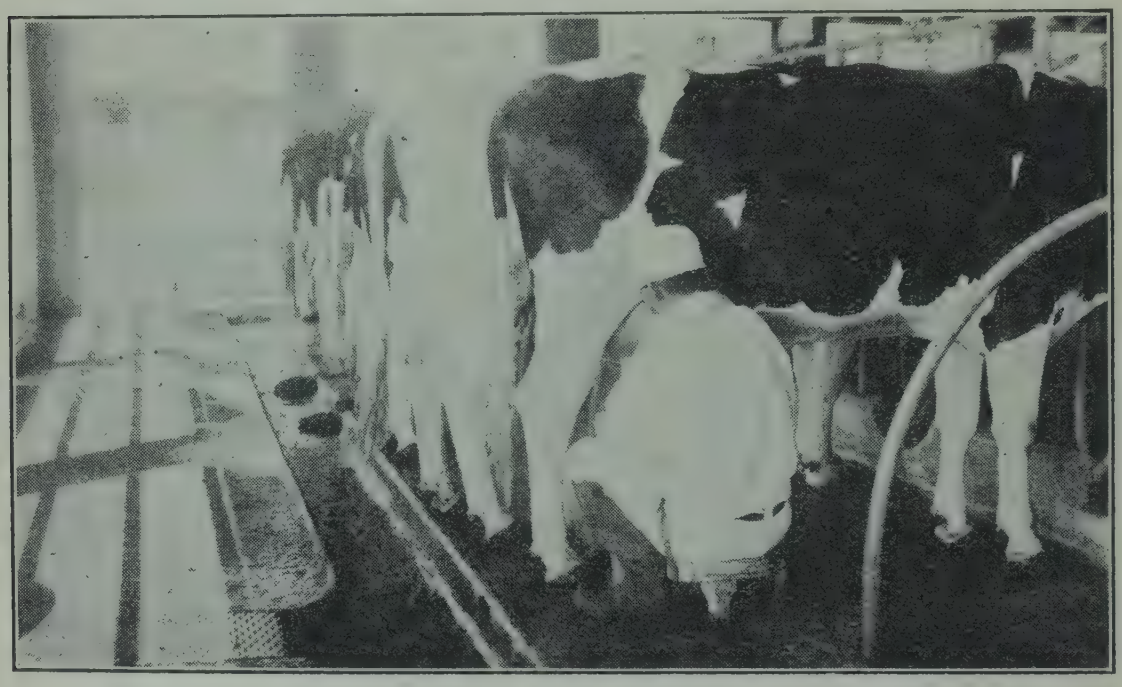

FIGURE 6.—Experimental dairy herd, University of Hawaii farm

is recorded. Service and calving dates and weight and sex of calves are also recorded, and graphs are on file showing the monthly milk production of each cow.

Tests are being made of the effect of feeding sprouted oats to breeding dairy cows. Half the animals failing to conceive are used as controls. As yet the data accumulated are not sufficient to permit drawing definite conclusions.

SWINE

The university farm maintains a small piggery of both Berkshires and Tamworths. These animals are used largely for instructional purposes, and their progeny is loaned for study to young men specializing in animal husbandry. The herds are also available for use in experiments undertaken by the Federal experiment station.

During the year an experiment was undertaken to determine the value of feeding sprouted oats to swine to overcome sterility.

REPORT OF THE CHEMICAL DIVISION

By J. C. Ripperton, C. Richter, and Elizabeth V. Harrold

EDIBLE CANNA

Studies begun in 1929, comparing the properties of edible-canna and potato starches, were completed, and a manuscript entitled, "The Physicochemical Properties of Edible-Canna and Potato Starches" was submitted for publication during the year. It was concluded among other things that (1) in a comparison of viscosity and swelling power by the methods devised in this work the former is not directly proportional to the latter; (2) the product of the concentration of starch times swelling power shows a fairly good proportionality with viscosity; (3) the curves of concentration times swelling power and viscosity for a number of potato and edible-canna starches roughly coincide; and (4) plotting the composite curve of the concentration-swell product and viscosity on semilogarithmic paper on the logarithmic scale causes the graph to become a straight line. This relationship makes it possible, by determining the swell at any given concentration, to find the viscosity in centipoises either by reference to a curve or by substitution in the equation of the curve. The swelling-power method, although not any more accurate than the viscosity determination, offers an advantage for factory control since it is rapid in operation and requires only simple apparatus.

Comparison of the properties of edible-canna and potato starches showed marked similarity with respect to temperature, length of time of cooking, and effect of electrolytes on viscosity and swelling power, canna starch being somewhat more affected than potato starch. In a continuation of the study of the relation of electrolytes to the properties of starches, depression in swelling power of the starches was found to coordinate closely with the valency of the cation, the numerical value of the depression being approximately 20 for monovalent, 30 for divalent, and 70 for trivalent cations. Treating raw starches with neutral salts of monovalent cations increased the swelling power and viscosity, whereas treating the swollen granules with the same kind of salts caused a depression. This was attributed to two different phenomena—the former being a chemical replacement of the cations of the starch granule with the monovalent cations, the starch of which had a greater swelling power than the original, and the latter, a physical adsorption which resulted in reduction of swell.

The extent of the substitution of the cations of neutral salts for those in the raw starch granule depends on the concentration of the salts and the number of treatments given. The effect of removal of the cations on the properties of the starch was studied by treating the starch with weak hydrochloric acid and by electrodialysis. Acid at a concentration equivalent to 0.002 had an effect comparable with electrodialysis. In nearly all instances removal of the cations caused the granules to burst on swelling. The fact that electrodialysis also produced this effect shows that bursting of the granules was not due to hydrolysis of the organic complex. Attempts to restore the original properties of the starch by resubstituting the cations were not successful by the method used, viz, that of shaking the starch with neutral salts and removing the excess by subsequent washing.

Investigations of the causes of differences in the properties of starches of the same species were continued. In both potato and canna starches preliminary data indicated that the high-viscosity starches were less saturated with cations, as was indicated by pH and titration curves, than were those of low viscosity. They also contained smaller amounts of calcium removed by displacement with sodium chloride and by electrodialysis. Potato starches contained markedly greater quantities of cations and phosphoric acid than canna starches.

The relative ease with which one cation may replace another in the raw starch granule suggested the possibility of government of the cations of the starch granule in the plant cell by the nature and concentration of the cell sap. If this were true, starches grown in

FIGURE 7.—Edible-canna plants growing in water culture to determine the effect of ion variation

the same locality over a period of years, or in various localities, would probably differ in electrolytes because of the variable factors of climate and culture. In the process of manufacture the use of water containing appreciable amounts of salts, or the use of bleaching agents, would seemingly alter the original cation content of the starch. It would also seem that these easily replaceable cations might serve an important function in the metabolism of the plant cell.

A new investigation was begun to determine the variations in the total and replaceable electrolytes contained in starches grown under different conditions of climate and culture. An attempt is being made to grow canna rootstocks in water culture for the production of a series of starches from plants grown under conditions differing greatly in the nature and the total concentration of the electrolytes used. (Fig. 7.) Methods are being developed to determine differences in the bonding of the cations to the starch granule, whether

they exist in different degrees of replaceability, and whether they have any relationship either to the cell sap or to the viscosity and swelling power of the starch.

Results of a commercial trial of a 6-ton lot of edible-canna starch were received by the station from a large starch distributor of the mainland. The distributor found the starch to be well adapted for use in making dextrin and for finishing textiles, two of the largest uses for the special starches. Canna starch could therefore be used as a substitute for cassava starch in dextrin and for potato starch in textile sizing.

MACADAMIA NUT

Further investigation of the variation in the composition of Macadamia nuts bore out the results previously obtained—viz, that maturity probably more greatly affects composition than do differences in climate and soil, or seedling variation. The oil content of the nut appears to increase and the sugars to decrease until the outer hull turns brown. Strong winds, or physiological conditions of growth, often cause a variable proportion of partly mature nuts to fall, with a consequent variation in the average composition of samples taken at different times from the same tree. The chemical division, working in cooperation with a local grower, selected 12 Macadamia-nut trees for study at biweekly harvests throughout the season. The various factors which affect composition and roasting qualities of the nuts were investigated. Samples of nuts from these trees are also to be used in a further study of improved methods for dividing nuts according to maturity.

Methods of grading Macadamia nuts according to the specific gravity of the unshelled nut have not been found to be entirely satisfactory because of the great variation in the thickness of the shell. The group with a specific gravity of less than unity contains some thin-shelled nuts with marketable kernels as well as badly shrunken, immature kernels. Work was therefore begun to learn the relation of the specific gravity of the kernel to its composition, in the hope of securing a more nearly accurate criterion for grading. To learn the degree of correlation between the oil content and the specific gravity, a series of nuts were selected covering the entire range of specific gravity from 1.05 to 0.96, and the oil and specific-gravity determinations were made, a single nut being used for each sample. Plotting these values gives a curve which shows very good correlation. With few exceptions, the deviation from the curve is less than 1 per cent. This method offers excellent possibilities as a rapid means of grading Macadamia nuts.

Experiments were begun to find the relation of roasting qualities to composition. The immature nuts when cooked in oil were found to turn dark rapidly and to develop a strong, rather unpleasant flavor, and a hard or tough texture. Under similar conditions of cooking the mature nuts were light brown, mild in flavor, and of crisp texture. The approximate dividing line between the desirable and the undesirable nuts is a specific gravity of 1, which on the curve is equivalent to an oil content of about 70 per cent. Nuts of a specific gravity greater than 1 did not seem to be satisfactory

for roasting purposes. The roasting qualities of the nut did not change perceptibly when the oil content was above a certain percentage.

As a result of the analyses made during the past two seasons, it is thought that two distinct varieties of Macadamia nuts are being grown in Hawaii. (Fig. 8.) The varieties differ outwardly in the surface of the shell, one being smooth and the other rough, and they differ in composition, the smooth-shelled variety containing an average of 76 per cent of oil and 4 per cent of sugar; whereas the rough-shelled variety contains an average of 67 per cent of oil and 8 per cent of sugar. In appearance, flavor, and roasting qualities, the two varieties are noticeably different. The smooth-shelled nuts have a crisp, nutty, but rather unpronounced flavor, whereas the rough-shelled nuts are less crisp and of a more pronounced, sweeter flavor. The roasting qualities of the rough-shelled variety are similar to those of the somewhat immature nuts of the smooth-shelled type.

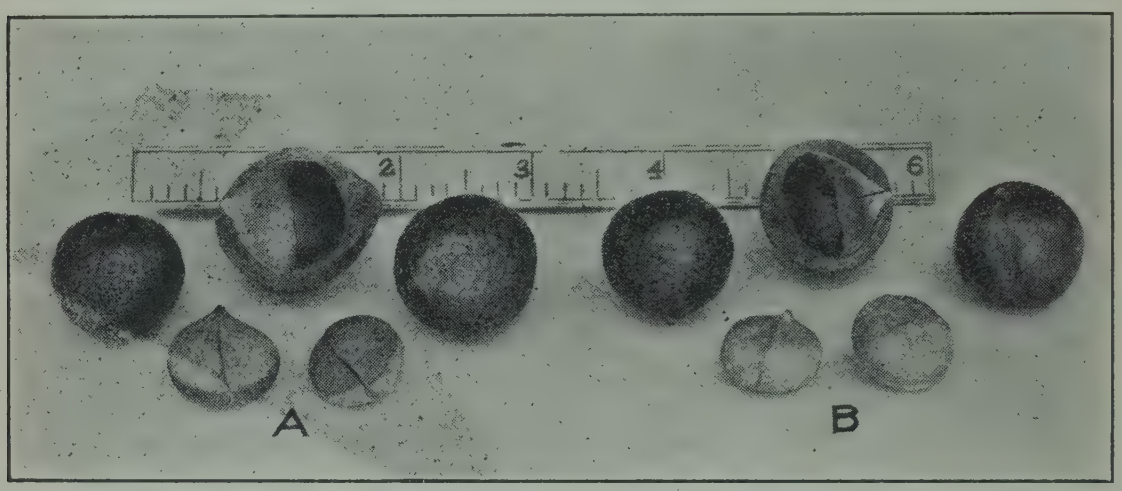

FIGURE 8.—Two varieties of Macadamia nuts grown in Hawaii: A, smooth-shelled variety, high in oil and low in sugar; B, rough-shelled variety, low in oil and high in sugar

COFFEE

SOIL SURVEY

The chemical division, in cooperation with the geologist of the Volcano Observatory, Geological Survey, continued its studies of the origin of the soils of the Kona district of the island of Hawaii. The evidence thus far obtained indicates that a definite mantle of volcanic ash gives rise to the fine uniform texture observed in certain areas of the Kona slope. Samples of the ash mantle at different altitudes, and of the decomposed scoria of the a-a lava flows were taken for analysis. The difference in origin is believed to furnish a feasible basis for a soil survey of the Kona district.

REJUVENATION OF OLD PLANTINGS

A cooperative experiment was begun in the Hamakua region, Hawaii, to determine the best method of renewing a 30-year-old coffee planting. For many years the trees have been kept topped, but they have not been pruned systematically. As a result they have made little growth and are largely a mass of old, unproductive laterals. (Fig. 9.) Methods under trial for renewing growth include

drastic thinning and pruning back; cutting off the trunk 1 foot aboveground to induce new top growth; and replacing dead and worn-out trees with seedlings from the Kona and the Hamakua districts. A fourth plat is being left to serve as a check, the trees there receiving no pruning. The experiment is being tried in a high, poor region, and also in a low, rich region. It is planned to fertilize one-half of each plat in the Hamakua district to demonstrate the practical value of fertilizers for coffee. No fertilizer has been used in this region.

SOIL-COLLOID STUDIES

Methods of measuring soil colloids were further studied by G. Richter, assistant chemist. The Bouyoucos' hydrometer method, which has become rather widely used since its proposal by Bou-

FIGURE 9.—Coffee tree about 30 years old showing the effect of continuous topping without thinning out of the laterals. The entire top has been partly lopped off to induce new growth from below. (June, 1930)

youcos in 1927, was investigated for application to tropical Hawaii soils. This method, which is based on Stokes' law of settling particles, was compared with the pipette method of mechanical analysis. The rapid hydrometer method, as suggested by Bouyoucos, for use when the variations in the specific gravities of soils are not taken into consideration was found to be sufficiently accurate for the routine classification of soils. The specific gravities of the soils used in this study varied between 2.2 and 3.3. This variation is much greater than in the case of mainland soils. A much better agreement was obtained between the pipette method and the detailed hydrometer method, which takes into account the specific gravity of soil and temperature conditions.

The temperature correction in the hydrometer method of mechanically analyzing soils, as proposed by Bouyoucos, was investigated.

He says that the corrections made should be the same for measuring all soil-suspension concentrations. The hydrometer is calibrated to give correct readings (grams solid matter per liter of water) at 67° F. Under or above this temperature 0.35 is deducted from or added to the readings for each degree under or above, respectively, 67°. The concentration of soil suspension and the range of temperature were found to play a rôle in the correction factor. Suspensions of the same soil at different concentrations but at the same temperature fail to give concordant results when the temperature-correction factor of 0.35 is applied for all concentrations. The same soil suspension which gives a certain reading at 67° will not give the same result at a higher or a lower temperature if the temperature-correction factor of 0.35 is applied unconditionally. In order to obtain concordant results, the correction to be applied per degree of Fahrenheit must become considerably smaller at the lower range of the hydrometer than at the higher range. Moreover, the corrections to be applied below 67° are different from those to be applied above 67°. On the basis of the findings a sliding-scale correction table to give concordant results at all concentrations is tentatively suggested.

Studies were begun to investigate the relationship between physical properties, especially moisture characteristics and the replaceable cations of the soil-exchange complex. For this purpose several varying soil types were saturated with the more common monovalent and divalent cations of the soil solution. The cations chiefly studied were hydrogen, sodium, potassium, ammonium, calcium, and magnesium. With mainland soils cations in the absorbed state were found to exercise an influence over physical properties. In addition to the theoretical importance of the investigation, certain practical considerations were found to be linked with the base-exchange and base-saturation phenomena, including the application and fixation of soluble fertilizers, the formation and accumulation of soil acidity, alkali-land reclamation, and the application of soil amendments, notably calcium. The question has long been debated whether the continuous application of sodium fertilizer results in undesirable changes in such physical soil properties as stickiness, plasticity, rate of water percolation, and texture. This investigation purposes to throw light on this question.

The estimation of the colloidal content of soils by the water-vapor adsorption method was studied with Hawaii soils. This method is based on the assumption that certain physical properties, such as water-vapor adsorption, are due largely, if not exclusively, to the colloidal fraction of the soil. The amount of colloids is estimated by determining the water vapor adsorbed by a soil and by a representative portion of the colloidal fraction of the soil which has been extracted. The ratio of the two figures obtained multiplied by 100 is taken as the percentage of colloidal material in the soil. This method fails to give correct results in many instances with both mineral and organic soils. The percentage of the so-called colloidal material, as estimated by this method, has been compared by several investigators with the colloidal-matter content as determined directly by sedimentation, assuming Stokes' law (pipette method).

The values obtained in the adsorption method are much higher than those obtained in the sedimentation method, the increases amounting to several hundred per cent in some instances. Similar results were obtained with Hawaii soils of both high and low organic-matter content.

No satisfactory explanation is advanced relative to the large disparity existing between two methods which are supposed to indicate the same thing. Organic material was often found to be present to considerable extent in the different silt fractions of Hawaii soils. This finding invalidates the assumption that all the organic material exhibiting adsorbtivity obtains in the colloidal fraction. Although all such organic material might really be of colloidal dimensions, existing in aggregates and resisting successfully all efforts of dispersion, it would nevertheless be classified as noncolloidal for all practical purposes. Furthermore, the chemical composition of the various fractions of the same soil, as indicated by the silica-sesquioxide ratio, vary considerably. For example, in one instance this ratio in the clay fraction amounted to 1.25, whereas in the silt fraction the ratio amounted to only 0.07. In another instance, the figures were 0.62 in the clay fraction and 1.41 in the fine silt fraction. It is known that the different chemical compounds involved in the inorganic phase of the soil differ widely in water-adsorbing properties, and that particles of much larger than clay or colloidal dimensions give considerable water-vapor adsorption. As a result of the investigation of the water-vapor adsorption method it seems inadvisable to attempt to translate physical properties into particle size, especially with soils of high organic-matter content, or with soils in which the chemical composition of the various fractions varies considerably.

AVOCADO PRESERVATION AND UTILIZATION

Studies of methods of preserving the avocado and its by-products were made during the year by E. V. Harrold, assistant chemist. Extensive work was done in canning, various methods of storing and freezing the fruit were tried, and special attention was given to methods of dehydration, pickling, and oil extraction.

In August, 1929, experiments looking to the development of the most practicable methods of utilizing the avocado were begun. The quarantine in effect on the fruit in the fresh state makes it necessary to process the avocado for exportation. The attack of investigators in other parts of the world on the problem was first studied. During the year over 200 different avocado formulas or recipes were tested.

Avocado-tomato cocktail combinations were tried in which green fruit and ripe fruit and fruit sauce containing different amounts of acid were used. The combinations tried were both hot and cold, and made with and without sodium benzoate. Different temperatures and lengths of time of cooking were tried with storage at 31° F. and under room temperature. Most of the samples spoiled or developed a rancid taste, and the cooked samples were bitter. A pleasing product was made by adding to avocado cubes in glass jars cocktail sauce which had been strengthened by the addition of

one-half of 1 per cent of acetic acid as vinegar. This product must be used within two weeks after it is removed from cold storage.

A tasty sandwich paste was prepared by putting peeled avocado through a meat grinder having a nut-butter attachment, and adding to 5 parts of the pulp by weight 1 part each of chopped sweet pickle, chopped pimento, mayonnaise, and 1 part of 100-grain vinegar, and finally one-tenth of 1 per cent of sodium benzoate. The bottles were filled to prevent excess browning of the contents by oxidation and then stored at 31° until wanted for use.

Fruit which was sulphured, presoaked in alcohol, pretreated with sugar, or with acid or salt, and then sun-dried, or dehydrated in a hot-air oven with a forced draft under different temperatures, became bitter, lost flavor and color, and upon being resoaked in water failed to regain texture, was of salvelike consistency, and very unpalatable.

Although canning the avocado in water, brines, diluted acid or sugar solutions, and heavy sirups resulted in an unsatisfactory product, a method was found of retaining the natural green and yellow coloring of the fresh fruit, which upon being heated turns mustard yellow in color. In this method avocado cubes, halves, or slices are soaked in pineapple vinegar until the liquid penetrates them. They are then removed from the vinegar and processed at 212° F. for at least 10 minutes, or at 160° for 20 minutes. The colors are obscured by the soaking process but are restored when the fruit is subjected to the temperatures above mentioned. When "60-grain" vinegar containing 6 per cent of acetic acid is properly used it seems to restore the natural colorings of the fruit. Vinegar of higher acidity was also found to restore color. Six per cent was satisfactorily used as the minimum strength in tests at the station. Avocados when thus treated to restore coloring may be combined with an equal amount of canned crushed pineapple to which fruit spices siruped with a 50 per cent sugar solution have been added. The combination should be exhausted for 10 minutes and processed for 30 minutes at 160° F. The sirup may be omitted.

Ripe and green avocados were placed in brines having strengths ranging from 5 to 20 per cent, and left under ordinary room temperature. Examination of the fruit at the end of one and two months showed that it was apparently perfectly preserved. However, after the fruit had been placed in fresh water to extract the salt, it was found to have lost its flavor, although in color and texture it remained perfect. Small, whole fruit when stored in brines having strengths ranging from 15 to 20 per cent kept well, but did not prove to be palatable. Tannin from the seed and from the skin permeated the fruit and predominated in the flavor.

The hard, green fruit from the above-outlined experiment was put up in pickle form in which sour, sweet, sweet-spiced, and salt-spiced liquors were used (*4*).[1] The spiced products were especially good, but none of them retained a distinct flavor. Any vegetable or fruit may be used as the pickle to flavor the avocado.

Olive-pickling treatments tried on the avocado were not successful. Oil was obtained from the fresh pulp of the avocado by the use of two methods without the preliminary dehydration usually con-

[1] Italic numbers in parentheses refer to Literature Cited, p. —.

sidered to be necessary. In the first method tried the finely mashed pulp was mixed with kieselguhr in the proportions of 6 to 1. It was then made into a press cake held in cheesecloth and put in a hydraulic press. Pressure was applied slowly at first and was strengthened when most of the moisture had been eliminated. In the second method tried a gallon of warm 2 per cent brine was added to about 5 pounds of mashed pulp and the whole allowed to stand for five days. It was then put through a supercentrifuge. Dehydrated avocados gave 2.5 per cent of dark, bitter oil that required much washing with alcohol and hot water. Under the pressure method the fresh pulp required only a few washings with warm water and when filtered gave 2.75 per cent of sweet, light, amber-colored oil. Under the centrifuge method the fruit gave 3.5 per cent of clear, light-green oil. Some of the chemical properties of these oils were compared. It is hoped that the iodized oil from the avocado can be successfully used in medical Röntgen-ray work. Experiments along this line are now under way. The press cake from the fresh fruit contains much protein, has a high fat content, and may make a good feed for live-stock. The dehydrated press cake can not be used because of its bitterness.

Cold-storage tests made under various temperatures with the whole fruit showed that the effect of time and temperature of storing varies with the variety. As a whole, Hawaii-grown avocados may be stored green at 36° F. for six to eight weeks. The fruit when removed from this temperature ripens satisfactorily within two to five days. Different kinds of paper wrappings and coatings of paraffin were tested to determine their value in prolonging the life of the fruit in storage. Results of these tests showed that the storage period should be even shorter, instead of longer, and that the fruit develops off flavors and colors. Fruits which were coated with paraffin rotted without ripening. Avocado cubes and halves were stored under temperatures ranging from 0° to 20° in diluted brines, vinegar, sirups, and water in paraffined cartons, in glasses, and in tin cans. Results showed that the containers should be tightly sealed to exclude foreign odors and air and prevent the browning of the fruit by oxidation. The frozen product can be kept indefinitely. The texture of the fruit was found to have gone completely when the samples were allowed to thaw, but the color was good in all instances and the sirups were of excellent flavor.

A satisfactory avocado pulp for use in ice cream was made by mixing 1 part of sugar with 5 parts of pulp and storing the mixture in sealed containers at 0° F. Having this pulp ready for immediate use was found to be advantageous. Plain and lightly salted pulps did not retain their color or flavor well. The pulp when mixed with a small amount of vinegar was satisfactorily used with salads and relishes, and for sandwiches.

Quickly freezing the whole fruit with carbon dioxide "snow" was not found to preserve the fruit satisfactorily. However, under proper conditions of freezing at −40° F., with subsequent storage at −10° or at zero, this method might be used to advantage. Hard, green fruit which was frozen did not ripen after it was removed from storage.

Results of quickly freezing the fruit in tin cans sealed in the air and sealed in vacuum without any liquid covering showed that the

vacuum pack was superior to the air-sealed product in color, texture, and flavor. Different varieties of fruit behaved differently when they were frozen. The Itzamna, Macdonald, and Wagner varieties of avocado gave the best results in texture of the lot tried, although none of the products had a distinctive avocado flavor. Freezing and prolonged storage seemed to destroy or to impair the flavor. Fruit which was frozen for four days was of excellent flavor when thawed.

Avocado halves which were frozen in direct contact with carbon dioxide "snow" and then stored for several months in screw-cap glass jars at zero retained a texture hardly distinguishable from that of the fresh fruit, but the product was flat and tasteless and after six weeks in storage lost its color.

The quininelike bitter principle that forms in the avocado when heated was a decided handicap to success in nearly all the work undertaken with the fruit. The bitter principle is soluble in ether,

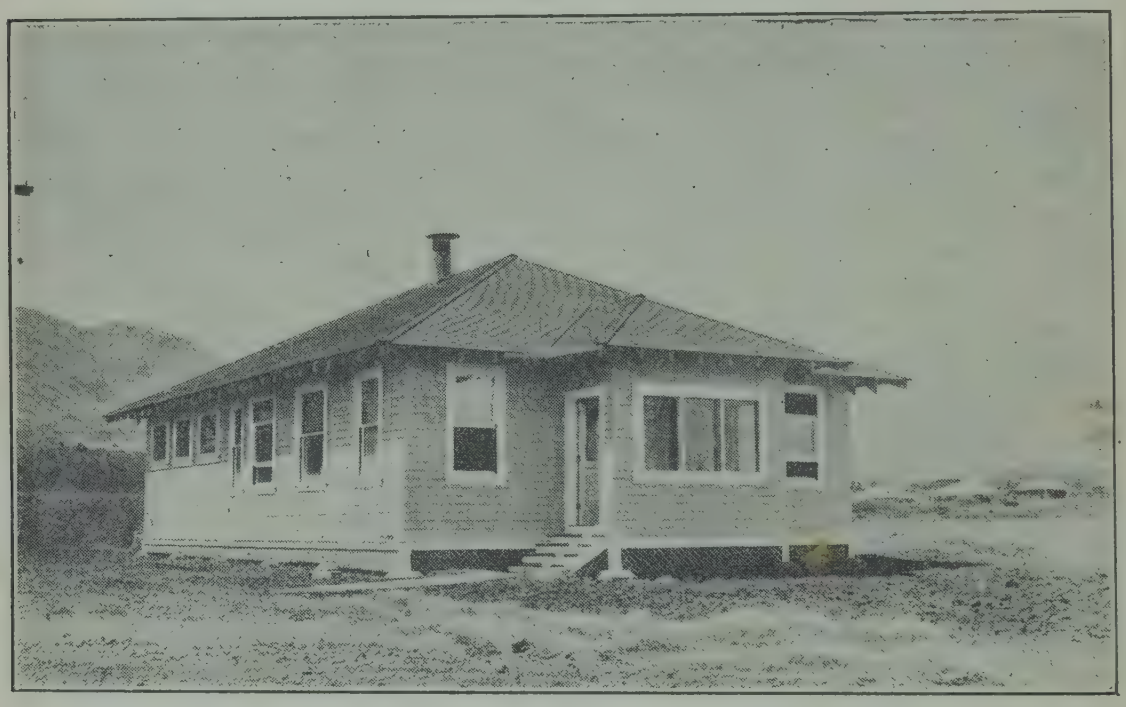

FIGURE 10.—New nutrition laboratory, University of Hawaii campus. Dairy buildings in right background

alcohol, and water. Its occurrence in the fruit is enhanced by treatments with weak acid, such as citric, tartaric, and acetic acids, but appears to be destroyed by 1 to 2 per cent solution of hydrochloric acid. Slow or quick freezing was found to destroy the bitter principle, or the components that cause it. Results of many experiments confirmed this fact with all the varieties of avocado tested.

REPORT OF THE NUTRITION LABORATORY OF THE HOME ECONOMICS DIVISION

By CAREY D. MILLER

A substantial wooden building occupying a floor space of 1,700 square feet was built and equipped as a laboratory during the first half of the year. This building is to serve as the nutrition laboratory. (Fig. 10.) Its facilities are excellent for assaying food, both chemically and biologically.

BREEDING ANIMALS FOR EXPERIMENTAL PURPOSES

A white-rat colony begun with 16 young animals in September, 1929, contained 26 rats of breeding age in June, 1930. During this period 153 healthy rats were born and used for breeding and other experimental purposes. Some difficulty in breeding was overcome by changing the feeding and housing arrangements.

The guinea-pig colony, begun with 6 animals early in the year, increased to more than 50 animals. A number of the pigs were unfortunately lost when they were treated for lice with sodium fluoride in too generous quantities.

VITAMIN C CONTENT OF ORANGES AND TOMATOES

A preliminary experiment comparing the vitamin C content in Hawaii and California grown oranges was begun during the year. The juice was fed to nine guinea pigs. As a result of the experiment the juice of the Hawaii-grown orange was found to be equal to that of the California-grown fruit in antiscorbutic properties. The experiment had to be discontinued sooner than was desirable, because the orange season came to a close more quickly than was expected. The experiment will be repeated during the local orange season, beginning in the fall of 1930.

Fifteen guinea pigs were used in a preliminary experiment comparing the vitamin C content of mainland canned tomatoes and locally and mainland-grown tomatoes in the fresh state. The negative control group was fed only a basal diet, whereas the positive control group was fed ample supplies of orange juice. The negative control group was fed the pulp of Hawaii and mainland grown tomatoes in the fresh state. Short periods of feeding and examination under the miscroscope of the teeth and the jaws of the animals, as is recommended by Hojer (*3*) and later by Eddy (*2*), are being employed in the experiment. Microscopic analyses have not been completed, but the indications are that locally grown tomatoes in the fresh state are higher in vitamin C than are similar tomatoes from the mainland. The superiority of the Hawaii-grown fruit is probably due to the fact that it is picked when fully ripe, whereas tomatoes from the coast region of the mainland must be picked when green for shipping to Hawaii. The experiment was temporarily closed, pending the breeding of sufficient animals for continuing it.

BIOLOGICAL VALUE OF THE PROTEIN OF THE PIGEON-PEA SEED

Forty-five rats were used in a preliminary experiment undertaken to determine the biological value of the protein of the seeds of the pigeon pea (*Cajanus indicus*). Ground pigeon-pea seed meal was fed in comparison with casein to determine the relative value of the two forms of protein. In future experiments purified protein from the pigeon-pea seed meal will be used. When pigeon-pea seed meal was fed in sufficient quantities to furnish 18 per cent of protein in the ration of white rats, growth and reproduction were satisfactory. This quantity of pigeon-pea seed meal also seemed to be sufficient to furnish enough of vitamins A, B (F), and G for normal growth. The pigeon pea is a very important stock feed in Hawaii, and the results of this preliminary experiment make it advisable to continue the study of the protein value of the crop.

CHINESE CABBAGE AS A FOOD

Chinese cabbage (*Brassica chinensis*) is one of the principal vegetables used in the dietary of the orientals in Hawaii. It is served both in the fresh and in the salted state. To date 34 rats have been used in an experiment testing the value of the vegetable, but it is too soon to draw definite conclusions.

REPORT OF THE HORTICULTURAL DIVISION

By W. T. Pope

COFFEE

Coffee occupies a comparatively small place in the agriculture of Hawaii, although as an industry it ranks fifth, following sugarcane, pineapples, beef production, and poultry raising, in the order named. Approximately 50,000 bags of coffee have been exported from Hawaii annually within recent years. Most of the regions in which coffee is grown in Hawaii are particularly adapted to its culture, as regards soil, temperature, and moisture, and protection from the prevailing trade winds. In many places the clouds afford a natural shade during the warmer parts of the day in summer.

Most of the growers lease the land from large landowners, and some of them plant the seedling trees entirely too close. Close planting may give early and perhaps larger returns per acre than would be the case if the trees were set farther apart, but in the course of 10 or 12 years it causes crowding to such an extent as to reduce yields materially. Crowding probably may be retarded somewhat by frequent pruning of the trees, but too much severe pruning soon results in stunted trees.

Very little attention is given to the selection of propagating material, and practically all the trees grown are seedlings. Propagation by seedlings is the natural method of producing numerous variations, but it lessens the margin of profit for the grower. A greater production on the same area of land will give increased returns. This will naturally encourage an extension of the area in coffee and cause the utilization of lands which at present are not producing commercial crops of any kind. The vital problem now confronting the coffee growers of Hawaii is that of increasing the production of high-grade coffee. Any possible increase in local production would be so small in comparison with the amount of coffee consumed in the United States as to have no effect on the selling price of coffee in American markets. Following the customary methods usually practiced in improving commercially grown tree crops, experiments now in operation have been planned with a view to standardizing Hawaii coffee by vegetative methods of propagation.

Top grafting mature fruit and nut trees is sometimes deemed necessary, especially when a growing period of 7 to 10 years is required for the tree to come into profitable bearing. Top grafting is not so important, however, with coffee trees which naturally come into profitable bearing in three to four years. It is important also that consideration be given to the selection of rootstocks which are resistant to unusual soil conditions, and particularly to nematode attack.

The species and varieties of coffee in Hawaii are not numerous, and difficulty in getting the different kinds of material for trial has considerably delayed the testing of resistant rootstocks. The only propagating material obtained by the Hawaii station from outside the Territory in recent years has been seeds of *Coffea arabica*, *C. excelsa*, *C. robusta*, *C. bukobensis*, *C. liberica*, and *C. quillou*. These were obtained from the Amani Research Institute, Amani, Tanganyika Territory, Africa. The seeds arrived at Honolulu in 1927, but were held by the Bureau of Plant Inspection. They were then forwarded to the Bureau of Plant Industry, United States Department of Agriculture, at Washington, D. C., and grown in quarantine for one year. The plants were then sent to Hawaii, where they were again kept in quarantine for another year before being utilized in the experiment. In January, 1930, sixteen 1-year-old plants of Hawaii coffee (*C. arabica*, No. 5497)[2] were obtained from W. A. Meyer, of Pukoo, Molokai, Hawaii. This particular stock is said to have been isolated for 50 years.

Coffee seedlings used in the experiment during the year included 460 Hawaii coffee trees (No. 5383) grown from station seed, 380 of which were distributed for cooperative experiments; 50 trees (No. 5381) from seed from Tanganyika Territory; 4 trees (No. 4135) from seed from a coffee company of Kona, Hawaii; and 32 trees (No. 3948) the original stock of which came from Java in 1917—all of the Arabian group (*C. arabica*); 13 Excelsa trees (No. 3947, 12 trees, the original stock of which came from Java, and No. 5382, 1 tree from seed from the United States Department of Agriculture)—all of the Liberian group (*C. excelsa*); and 1 Robusta tree (No. 5948) of the robustoid group (*C. robusta*) from seed from Tanganyika Territory.

About 200 seedlings of these coffees were planted at the Tantalus substation at an elevation of about 1,000 feet. Most of the trees were set on a hillside which is somewhat sheltered by large mango and eucalyptus trees. The coffee has not done well in the more heavily timbered plats, but it has made fair growth in the clearings and in the areas of medium to light shade.

Vegetative methods of propagation with the small amount of material available at the Pensacola Street station gave little satisfaction, probably because the material used was in rather poor condition. Seedlings which were grown in compartively small containers were hard to get into proper condition for grafting.

Methods of pruning coffee trees were studied in the Kona district of Hawaii. Several methods are employed by the growers, but none of them offer advantages. It is believed that a system of pruning should be worked out to apply to grafted trees that are properly spaced and cultivated.

MACADAMIA NUT

Special investigations with the Macadamia nut were in progress during the year. Four hundred vigorous seedlings have been developed from the several selected trees growing at the Tantalus substation. These seedlings are to be used as rootstocks in further work developing standard varieties. The experiments are being started at

[2] Number under which the trees were received at the station.

both the Pensacola Street station in Honolulu and at the Kona substation, Hawaii. A portion of these trees is being grafted in gallon-size containers so that transplanting can be done without disturbing the soil about the roots. Others are being set in orchard form and top grafted as soon as they show evidence of having become established permanently in the orchard. Rooting cuttings as a means of propagation has not given success at the central station, even when the trials were made under several different conditions. Arrangements are being made, however, to try the method at the Kona substation where climatic and soil conditions are better. The importance of vegetative propagation is becoming more evident each year. A great many additional trees came into bearing during the early part of this year, and marked variation in the nuts of certain trees was noted. Several orchards in different parts of the Territory contain unusual trees which have come into bearing for the first time. Among these are trees with unusually large nuts and others with nuts having comparatively thin shells. The Macadamia-nut trees are also showing numerous other variations including differences in vigor, nature of foliage, time of flowering, and productiveness. During the year the horticulturist made a trip to the orchards on Oahu and Hawaii for the purpose of inspecting and studying the trees there. He found growers enthusiastic about their orchards and anxious to have them developed rapidly.

A bulletin on the Macadamia nut was issued during the year (*5*). This bulletin gives the results of experiments recently completed, and likewise a general discussion of the history, botanical relationships, and cultural requirements of this comparatively new nut tree.

AKALA OR NATIVE RASPBERRY

Six commercial varieties of raspberries—Lloyd George, Cuthbert, Herbert, Seneca, Latham, and Ranere—were introduced into Hawaii through the kindness of George L. Slate, of the New York State Agricultural Experiment Station, Geneva. These plants were in transit about 14 days. All were immediately set in 7-inch pots of sterilized soil, and some time later 61 per cent of them were found to have survived. This introduction was a continuation of the work started last year when varieties were obtained from several other parts of the mainland of the United States. It is planned to use these varieties in cultural tests and hybridizing experiments.

In the summer of 1929 further study was made of the wild native raspberry (*Rubus hawaiiensis*), several localities in the mountains of the island of Hawaii, each differing in elevation and in rainfall, being visited for the purpose. In the forest reserve on Hualalai Mountain, where the elevation is about 4,500 feet and the average annual rainfall amounts to 100 inches, akala plants make rank growth, often reaching a height of 8 to 10 feet. The crop is not large, but the individual fruits are very large and juicy. In a timber-line region on the same mountain where the elevation is about 6,000 feet and the annual rainfall varies from 30 to 50 inches, the trees are few and stunted in growth, and vegetation in general consists of scattered bushes and other small plants such as are adapted to the higher elevations of Hawaii. Akala plants 4 to 5 feet in height are found growing in many places in this region, and in early

summer they are heavily loaded with large, firm fruit, which is rather tart but of fair flavor when fully ripe. The young plants, like those in the rainy forest, apparently have developed from seeds dropped by birds. The fruit is borne on short side spurs on the young wood, each spur producing five to nine berries averaging about an inch in diameter, although larger specimens are common. Berries of both yellow and purple-fruited varieties of *Rubus hawaiiensis* were collected and put into different preservatives for laboratory work. Seeds desired for propagating purposes were prepared for shipment by selecting ripe berries and thoroughly mashing and mixing them with a quantity of rich, damp mountain soil. A few days later the material was forwarded to the Pensacola Street station, Honolulu, where it was spread as a surface layer over other prepared soil in germinating flats. (Fig. 11.)

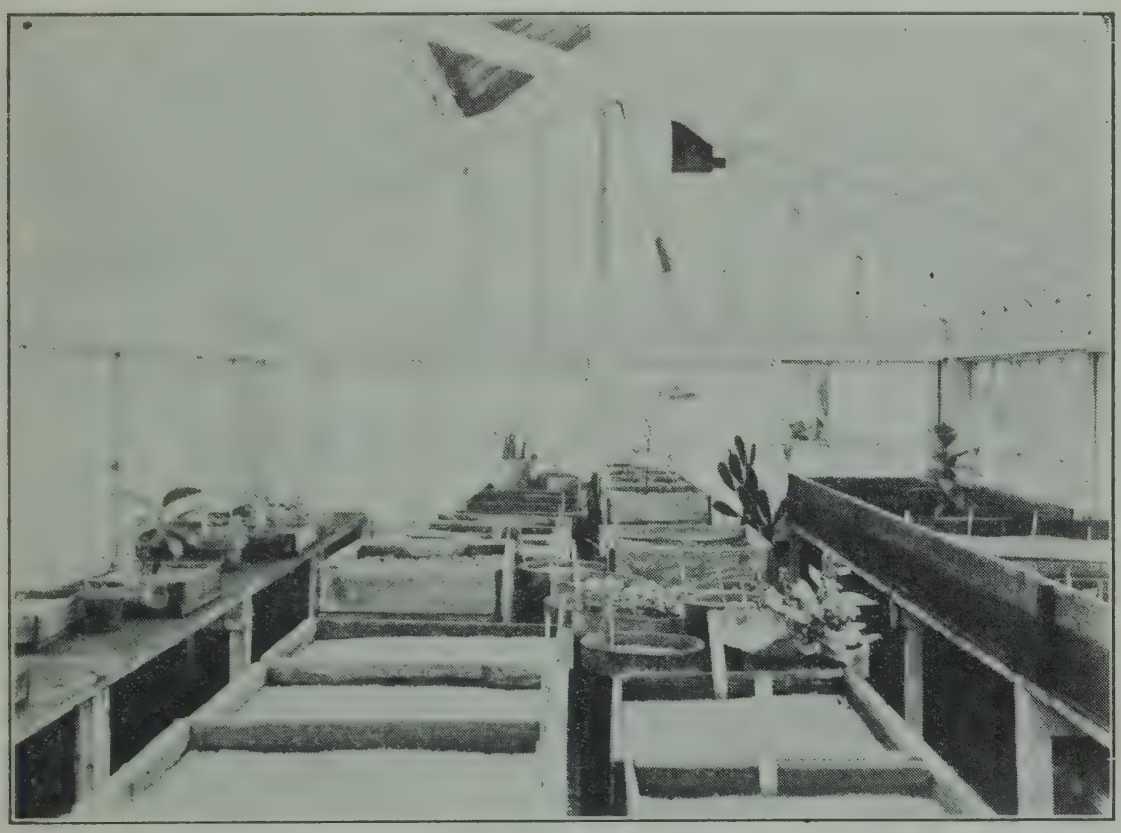

FIGURE 11.—Propagating flats used in akala seed germinating tests

During the past few years no akala seeds have germinated at the station even when they were dried for a few days before being planted. Like the seeds of many other species of tropical fruit plants, including those of the mangosteen (*Garcinia mangostana*), lanzon (*Lansium domesticum*), litchi (*Litchi chinensis*), mountain-apple (*Eugenia malaccensis*), and Brazil cherry (*E. brasiliensis*), the seeds of the akala are sensitive to drying.

In one locality on the west slope of Mauna Loa, where the elevation is about 6,200 feet, a variation of *Rubus hawaiiensis* was found growing over a considerable area of land. All the plants of this form bore oblong fruit on long fruitstalks. Individual ripe fruits were 1⅛ to 1¾ inches long. Akala plants in a near-by locality all bore yellow fruit of spherical shape and averaged 1 to 1¼ inches in diameter.

A study was made of the Rubus species growing in a part of the large Kau forest reserve on the east side of the volcano Mauna Loa.

The Kau forest is separated from that of Kona on the west side by a barren plateau which is 15 to 25 miles across and about 3,000 to 4,000 feet above vegetative growth; and also by numerous comparatively recent barren lava flows on the north and the south, extending from great fissures high upon the slope down to the sea. The Kau forest in many places is dense, particularly the underbrush, of which the akala (*R. hawaiiensis*) forms a portion. A foot trail was followed up the mountain slope to an elevation of about 5,000 feet. Practically all the akala plants observed were found to be tall and of spindling growth, a condition presumably caused by the crowded undergrowth of the forest. The crop was light and none of the fruits measured an inch in diameter. Both yellow-fruited and purple-fruited plant material was collected for propagation and laboratory purposes. All the akala plants observed in this region were spineless. The forest ranger, however, stated that spiny plants grow in some other parts of the reservation. No plants of *Rubus macraei* were seen, but at an elevation of about 3,000 feet a number of plants of the blackberry (*R. laciniatus*) were found growing. Birds presumably brought the seeds to this unusual place, as the species is common along the road approaching Kilauea Volcano from the Hilo side some 30 miles away.

Early in the year some experiments with species of Rubus were begun at the Tantalus substation on a rather steep slope at an elevation of 1,000 feet. The soil in this region is made up of decomposed volcanic cinders and supports a forest growth mostly of mango and eucalyptus trees. Shrubs, vines, and much honohono (*Commelina nudiflora*) form the undergrowth. Since both akala and coffee grow in the mountainous woods of many localities, it was thought that they might do well in this forest. Rubus plants were accordingly spaced 16 feet apart in the row and interspaced with young coffee trees, along contours. Water was provided for the plants from a near-by source in case of drought. Included among the Rubus species were 170 plants of akala (*R. hawaiiensis*) which had been grown at the Pensacola Street station from seed collected the previous year, 10 varieties from the mainland of the United States, and 1 species from the Philippines. The plants were severely attacked by the Japanese beetle (*Adoretus tenuimaculatus*)[3] notwithstanding the fact that they were given every possible care.

In September, 1929, cooperative experiments with Rubus species were begun in the Kona district of Hawaii. Plantings were made in four places varying considerably in elevation and in rainfall. Of these plantings, 18, representing 9 varieties, were set at an elevation of 1,950 feet in a very moist locality of the Macadamia Nut Co., Keahou mauka; 24, representing 10 varieties, including 6 akala plants, were set at an elevation of 1,500 feet in a moist locality on the farm of T. C. White, Kealakekua; 10, representing 4 varieties, were set at an elevation of 2,000 feet in a dry locality on the Huehue ranch, North Kona; and 10, representing 4 varieties, were set at an elevation of 2,750 feet in a very dry locality on the Puuwaawaa ranch.

[3] These beetles attack many kinds of plants of the family Rosaceae. The beetles are so numerous as not to be held in check satisfactorily by poison sprays. One horde of beetles may be fatally poisoned and be quickly succeeded by several other hordes which do additional damage to the plants before succumbing to the poison.

CITRUS

The citrus orchard maintained at the central station in Honolulu is an accumulation of miscellaneous species and varieties that were introduced from various sources. This orchard in addition to serving for experimental purposes is also a source of propagating material for use in numerous cooperative experiments throughout the Territory. The orchard is small, and at present contains 12 varieties of oranges, 5 varieties of lemons, 14 varieties of pomelos, 4 varieties of limes, 5 varieties of mandarins, and 12 kinds of miscellaneous citrus hybrids. Plants of several Siamese varieties of pomelo and half a dozen new hybrids were recently obtained from the United States Department of Agriculture, Washington, D. C. These will in time form a part of the station orchard.

Considerable interest in citrus growing, particularly oranges and lemons, is being shown in several parts of the Territory. The con-

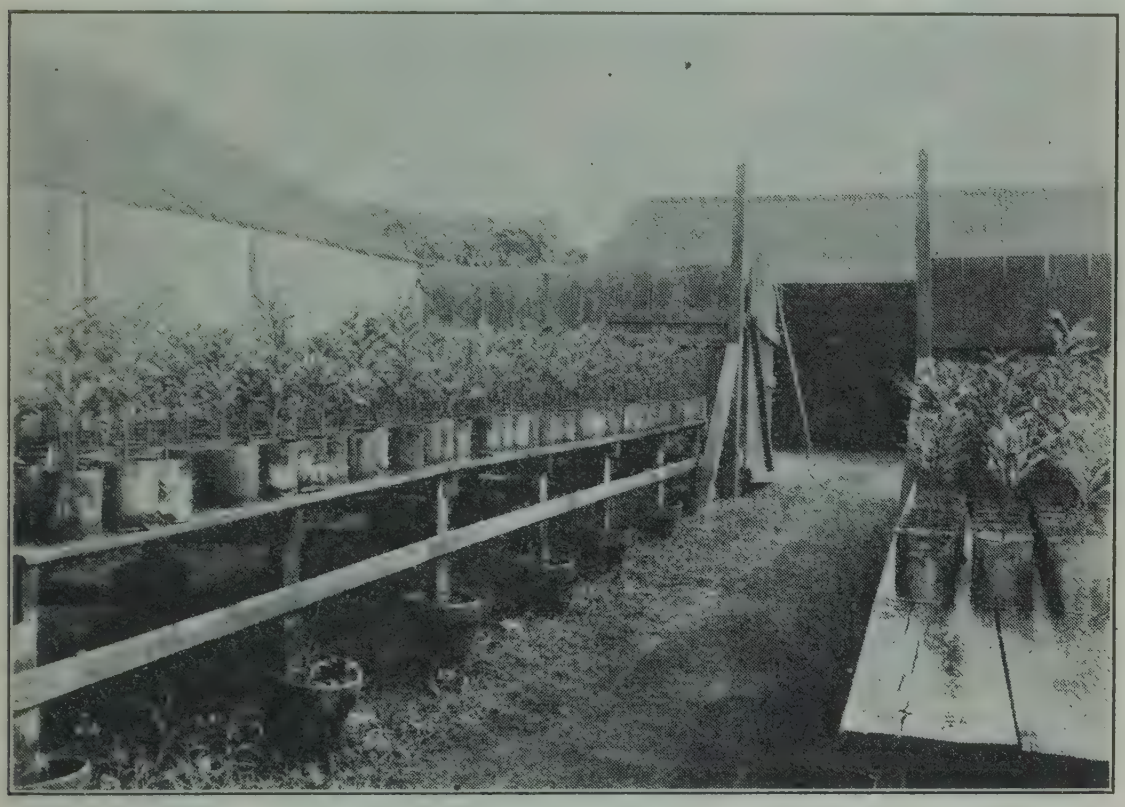

FIGURE 12.—Pomelo seedlings of the shaddock type growing in the nursery for rootstocks for grafting citrus

sumption of these fruits has greatly increased within the past two years, importations have been much greater than ever before, and the fruit has retailed at unusually high prices. Another matter of encouragement to the local producer is the lessening in some localities of the ravages of the fruit fly on oranges, lemons, and pomelo of the shaddock type. Careful study of the requirements of citrus of this kind should enable growers to produce profitable crops on large areas of land. One of the present experiments has for its object the development of a method for utilizing the different varieties in order to extend the fruiting season over a much larger portion of the year than is now the case.

The importance of using vegetative methods for propagating the citrus is well known. Much experimental work has yet to be done in this line because Citrus species and the variations under which

they are cultivated are numerous. For good results the tree is rather exacting in its requirements of temperature, moisture, and soil. One of the present experiments deals with a study of resistant rootstocks. As has been shown by experiments in recent years pomelo seed-

FIGURE 13.—The Hak-ip variety of litchi growing at the Pensacola Street station

lings of the large-fruited shaddock type make the best rootstocks on which to graft most of the kinds of citrus in Hawaii. Such seedlings are now being used at the station. (Fig. 12.) They may be grown from seed to a suitable size for grafting in about 10

months. At this age the seedlings are 14 to 18 inches high and have a stem diameter of about five-sixteenths to seven-sixteenths inch at the point where the graft is to be made. This graft is made in the stem at a distance of 6 inches above the ground. Bark grafting or wedge grafting may be used, and the parts will be found to have united sufficiently in about two months to permit transplanting the tree to the orchard. Such seedlings can be successfully developed and grafted in the field, but in this case the scion may fail and a new seedling will have to be planted. Results of tests with the fruit of different varieties produced in the orchard show that quality is greatly influenced by the temperature and the moisture conditions prevailing during development.

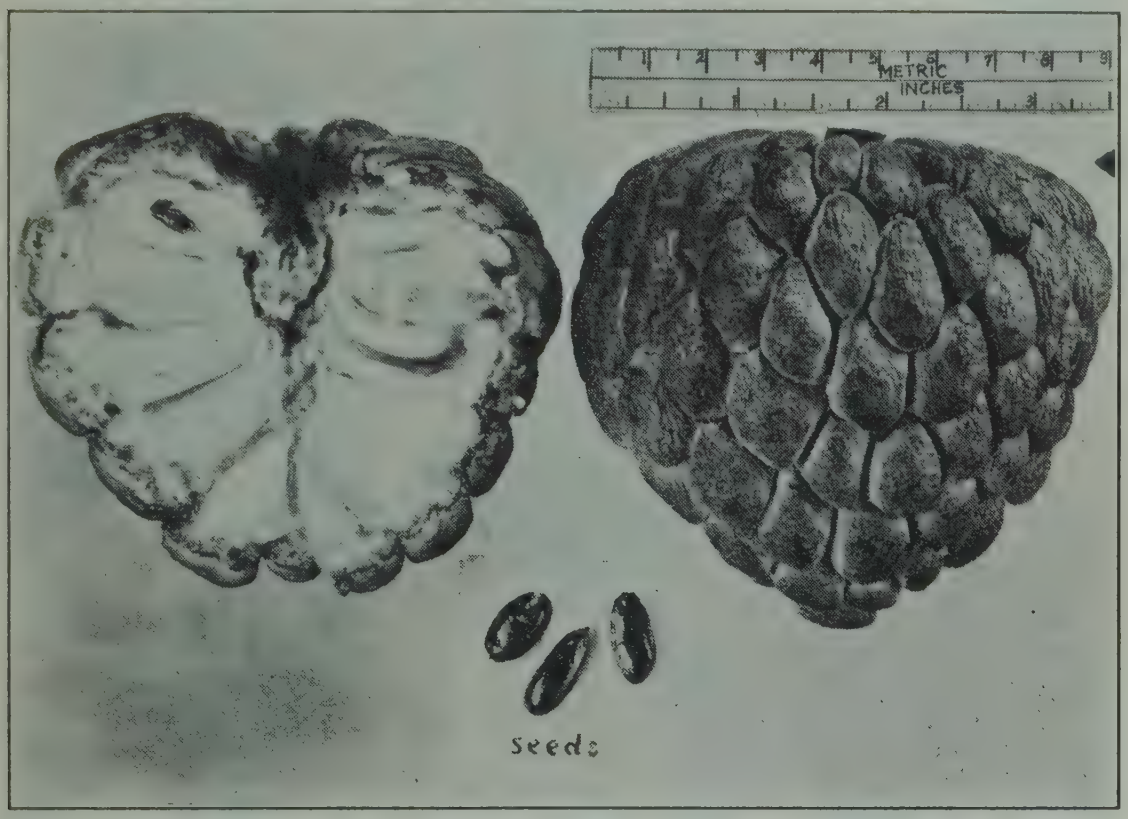

FIGURE 14.—The sugar-apple (*Annona squamosa*). This fruit is suitable for the lower elevations in Hawaii

MISCELLANEOUS NOTES

A number of fruit and nut plants were under investigation during the year. Attention was centered on those of greatest importance to the Territory, including the avocado, banana, breadfruit, citrus, coconut, date, grape, litchi, Macadamia nut, mango, mountain apple, mulberry, papaya, poha, pineapple, strawberry, and tomato. Results of experiments with practically all these plants have been discussed at some length in former reports of the station, and the general habits, culture, and uses of the avocado, banana, citrus, litchi (fig. 13), Macadamia nut, mango, and papaya have been discussed in bulletins of the station.

Considerable attention has been given to certain fruit and nut plants of promise which as yet have not been grown to any great extent commercially in Hawaii. Interest in them is increasing. These plants include the soursop (*Annona muricata*), custard-apple (*A. reticulata*), ilama (*A. diversifolia*), sugar-apple (*A. squamosa*) (fig. 14), cherimoya (*A. cherimola*), cashew nut (*Anacardium occi-*

dentale), mangosteen (*Garcinia mangostana*), lanzon (*Lansium domesticum*), mabolo (*Diospyros discolor*), granadilla (*Passiflora quadrangularis*), the fragrant passion fruit (*P. alata*) (fig. 15),

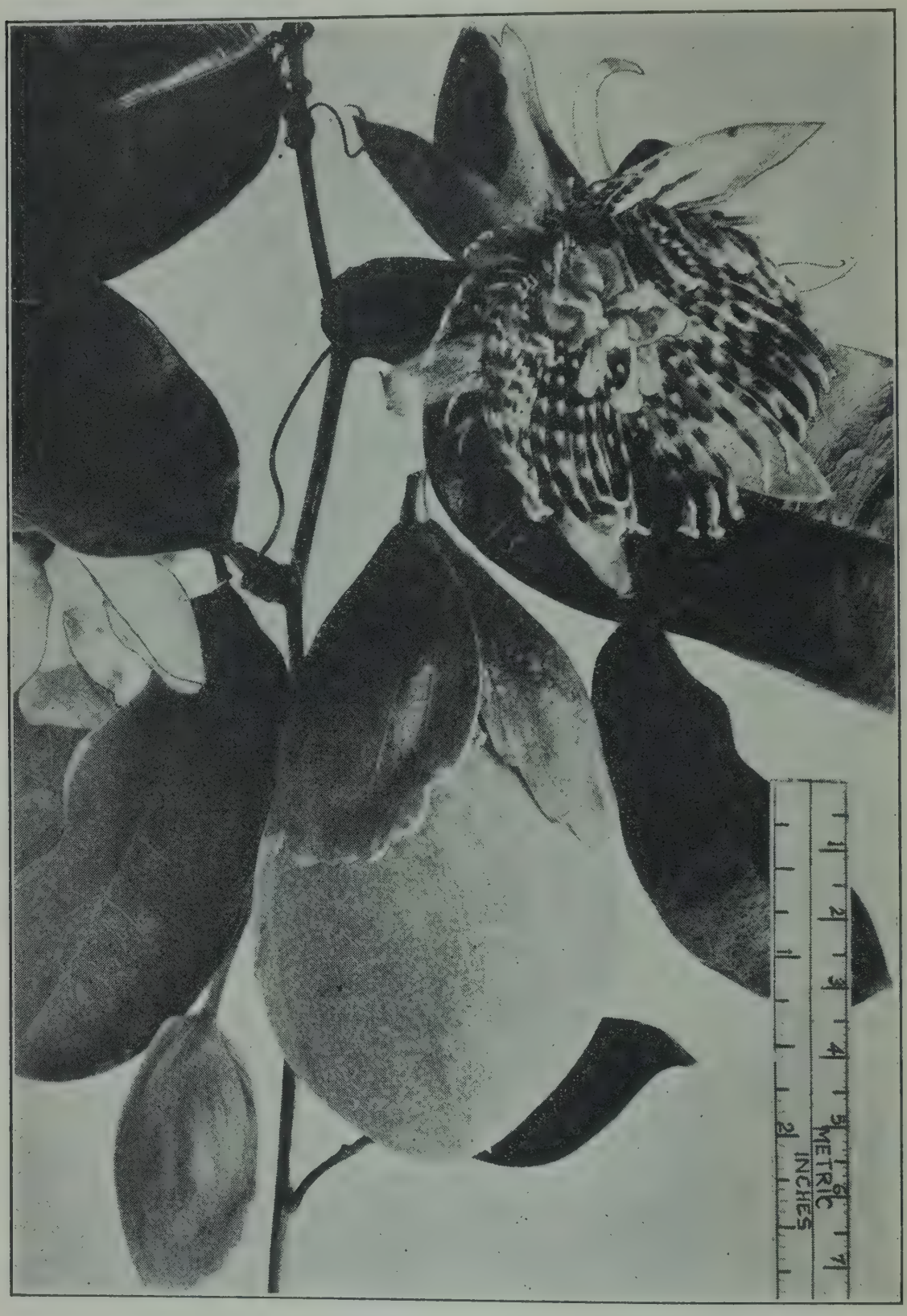

FIGURE 15.—*Passiflora alata.* A very excellent edible fruit

waterlemon (*P. laurifolia*), purple-fruited waterlemon (*P. edulis*), and the large waterlemon (*P. ligularis*).

Propagating material of 77 species of fruit plants, either new to the Hawaiian Islands or rarely cultivated there, was obtained

during the year, and in most instances is being experimentally developed. The following are the more important of the plants under trial:

Akala berry (*Rubus hawaiiensis*). An unusual fruit, large, oblong, on long fruitstalk. Plant (No. 5452 [4]) received from Greenwell ranch, west slopes of Mauna Loa, Hawaii.

Bigaraldin (*Citrus* sp.). Two plants (No. 5504), representing a cross between sour orange and *Citrus mitis*, and grafted on a stock of citremon. Received from the Bureau of Plant Industry, United States Department of Agriculture.

Binukao (*Garcinia* sp.). Probably *Binuaco* sp. A small tree (No. 5458) with an edible, acid fruit.

Biribá (*Rollinia deliciosa*). An annonaceous fruit plant (No. 5456) from the Philippines. Native of northern Brazil and Guiana. The fruit, which is excellent, resembles the custard-apple in appearance.

Blueberry (*Vaccinium myrtilloides*). Three plants (No. 5469) received from the Bureau of Plant Industry, United States Department of Agriculture.

Breadfruit (*Artocarpus incisa*). The variety Kuru Peka (No. 5446) from Rarotonga. The variety Kauhina (No. 5471) the rooted cuttings of which came from Papeete, Tahiti. One root cutting (No. 5472) from Papeete, Tahiti. The variety Kuahe (No. 5473) two root cuttings of which came from Tahiti, South Seas. Two root cuttings (No. 5474) from Tahiti. The variety Ula Maopo (No. 5491) from Tahiti.

Bulso (*Gnetum indicum*).. A large, woody vine (No. 5448), the seeds of which in the Philippines are used as nuts.

Canarium insulare. A nut-bearing tree (No. 5450) of unusual variety from Rarotonga, Cook Islands, South Seas.

Cashew nut (*Anacardium occidentale*). Two seedling trees (No. 5461) from a local nursery. The tree is of economic value for its edible fruit and nut.

Chocolate tree (*Theobroma cacao*). Trees (No. 5445) producing cocoa and chocolate from Rarotonga, South Sea Islands. One hundred and twenty-five seeds (No. 5492) from Papeete, Tahiti.

Citrus sp. Hybrid (No. 5509) resulting from crossing King orange and grapefruit and grafted on a citremon (*Citrus trifoliata*×lemon).

Coffee (*Coffea arabica*). A Hawaiian type (No. 5497) 16 seedlings of which were received from Molokai, Hawaiian Islands.

Dalinsi (*Terminalia edulis*). Used as a preserve fruit in the Philippines, whence it (No. 5442) came.

Dauag (*Capparis micracantha*). A shrub (No. 5457) producing bright-red, edible fruit. From the Philippines.

Duhat (*Eugenia cumini*). An ornamental fruit tree (No. 5444) from the Philippines.

Garcinia binucao. Tree seeds (No. 5498) from the Philippines.

Guava berry (*Eugenia lineata*). A golden-yellow variety (No. 5475) and a dark-red variety (No. 5476) from the Bureau of Plant Industry, United States Department of Agriculture.

Hibiscus spp. Seeds (No. 5486) from the Philippines.

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[4] Number under which plants were received at the station.

Kapok (*Ceiba acuminata*). A tree (No. 5460) of economic importance the seeds of which came from the University of Hawaii, Honolulu.

Kubili (*Cubilia blancoi*). Seeds (No. 5495) from the Philippines. The seeds are edible.

Lamio (*Dracontomelum edule*). A fruit tree (No. 5447) from the Philippines.

Lemon (*Citrus limonia*). A red variety (No. 5477), 56 seeds of which came from the Fiji Islands, South Seas.

Libato (*Basella rubra*). A trailing vine (No. 5459) the leaves of which are cooked and eaten in the Philippines like spinach.

Macadamia nut (*Macadamia ternifolia*). Six large nuts (No. 5481) from Hoaeae ranch, Oahu. Several nuts of a thin-shelled variety (No. 5482) from Hoaeae ranch, Oahu.

Oroxylum indicum. Eighteen seeds received of a tall tree (No. 5516) of economic importance.

Papaya (*Carica papaya*). Seeds (No. 5454) received of a good individual fruit grown in Papeete, Tahiti.

Parkia timoriana. Five seeds (No. 5515) received from the Philippines.

Passiflora sp. Seed (No. 5478) received from the Fiji Islands.

Perunkila (*Carissa* sp.). Used as a jam fruit in the Philippines whence it (No. 5443) came.

Pia or arrowroot (*Tacca pinnatifida*). Tubers (No. 5493) received from a grower on the island of Hawaii.

Pomelo (*Citrus grandis*). A sweet fruit (No. 5512) obtained from Chock Chin of Hanalei, Kauai.

Raspberry (*Rubus* spp.) Sixteen plants of the Lloyd George variety (No. 5463), 15 plants of the Cuthbert variety (No. 5464), 15 plants of the Herbert variety (No. 5465), 15 plants of the Latham variety (No. 5466), 15 plants of the Seneca variety (No. 5467), and 15 plants of the Ranere variety (No. 5468), all from the New York State Agricultural Experiment Station, Geneva, N. Y.

Santol (*Sandoricum koetjape*). An Indian fruit tree (No. 5451) from the Philippines.

Sapucaia nut (*Lecythis sabucaja*). Two seedling trees (No. 5462) from a local nursery. This species is valuable for its rich edible nut. It is a native of tropical South America. Fifty seeds (No. 5484) from the Bureau of Plant Industry, United States Department of Agriculture.

Siamelo (*Citrus* sp.). A hybrid (No. 5505) resulting from crossing King orange and grapefruit and grafted on a citremon (*Citrus trifoliata*×lemon).

Siamese pummelo (*Citrus* sp.). Variety Kao Panne (No. 5500). Variety Kao Panne (No. 5501). Variety Kao Phuang (No. 5502). One rooted cutting (No. 5503). All from the United States Department of Agriculture.

Sugar-apple (*Annona squamosa*). Fifty seeds (No. 5490) from local growers.

Solanum sp. Package of seeds (No. 5483) from Java via the Philippines.

Tangelo (*Citrus* sp.) A hybrid plant (No. 5506) received resulting from a cross between a tangerine and a grapefruit and grafted

on sapodia (sour pomelo×sour orange). One tangelo plant (No. 5507) received. Tangelolo (No. 5508), a hybrid resulting from crossing tangelo and grapefruit. Two plants received. All from the Bureau of Plant Industry, United States Department of Agriculture.

Terminalia sp. An ornamental (No. 5449) with an edible nut from Rarotonga, Cook Islands, South Seas.

Thunbergia sp. This species (No. 5499) from the Bureau of Agriculture, Philippines.

Tithonia speciosa. Seeds (No. 5485) from the Philippines.

REPORT OF THE POULTRY HUSBANDRY DIVISION

By C. M. Bice

The university farm maintains a flock of approximately 2,000 chickens of standard breeds for instructional purposes and for use in

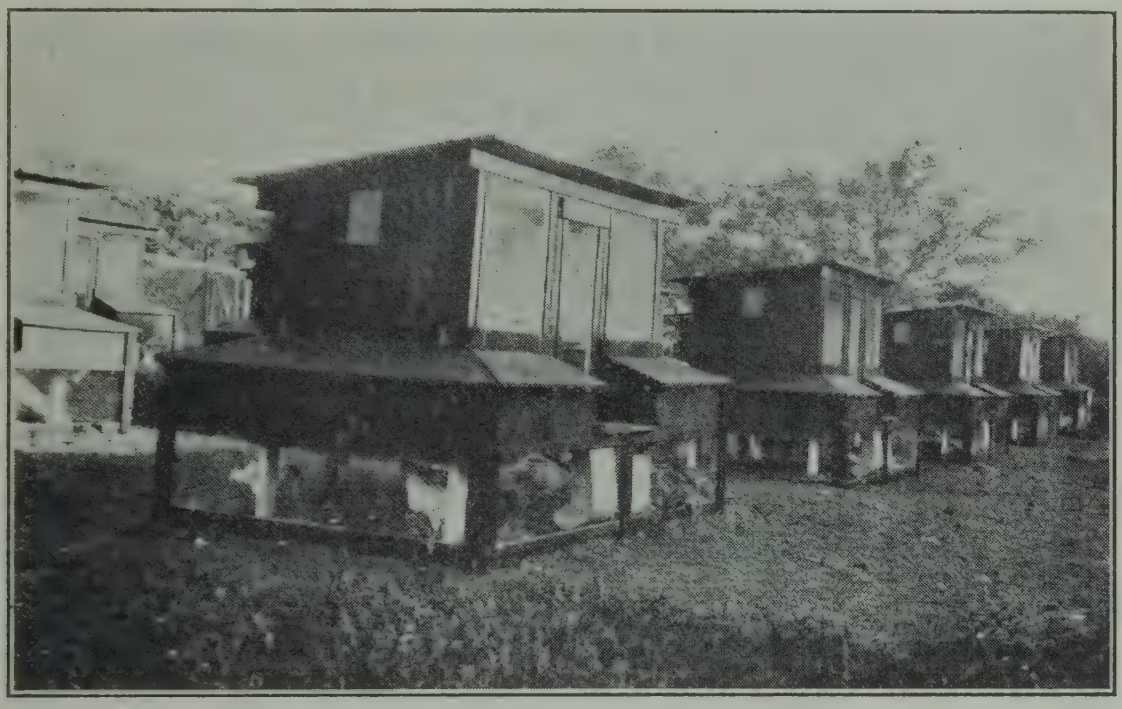

Figure 16.—Poultry houses, University of Hawaii farm

projects carried on by the experiment station. Five of these projects were under way during the year. (Fig. 16.)

SOREHEAD (FOWL POX) CONTROL IN BABY CHICKS

Sorehead (fowl pox) is probably the most destructive of any of the local poultry diseases. The mortality of chicks from fowl pox in Hawaii ranges from approximately 25 to 45 per cent of the total number of chicks hatched yearly. The disease is widespread throughout the Territory, and appears each year. Fowl pox has been identified as Epithelioma contagiosum by Dr. O. N. Allen, of the University of Hawaii. An experiment was begun to determine how the disease is transmitted to baby chicks with the hope of devising practical methods for its control. One thousand baby chicks one day old were divided into five equal groups and kept under different conditions of housing and yarding. Five brooder houses and runs

were used in the experiment, three of which were entirely mosquito-proof. The chicks were confined in these houses until 13 weeks of age, when they were transferred to the laying house or to small colony houses for further study. One of these small colony houses was made mosquito-proof but had a run which was not mosquito-proof; the other house and its run were not mosquito-proof. Twenty-five chicks were placed in each of these houses. Twenty-five chicks were placed in another small colony house and given access to the ground. In every instance except the latter the chickens were kept off the ground by means of a ½-inch mesh hardware wire floor or a concrete floor. Records were kept of the number of birds in each house, the number of cases of sorehead, and the number of deaths from the disease. Characteristic sorehead lesions appear 7 days after the mosquito has fed on the chick. The findings appear to confirm those obtained in preliminary experiments along this line and previously reported, viz, that sorehead is transmitted to baby chicks by mosquitoes and may be prevented by screening the runs and houses (*1*).

SEX DETERMINATION IN DAY-OLD PUREBRED CHICKS

Attempts were made to find in day-old purebred chicks some definite sex-linked character, which is always present and readily observable, other than by extremely close scrutiny, preferably with a hand lens, of the internal organs. Most of the studies dealt with the tonal characters of the "peep" uttered by the chick when it was picked up. Some of the tests showed as high as 68 per cent correct determinations. However, the use of any method giving less than an average of 90 per cent is not considered to be commercially feasible.

FEEDING

HAWAII MINERALS FOR POULTRY

Experiments were undertaken to determine the comparative efficiency of Hawaii minerals with oyster shells and with poultry bone and the like for egg production, fertility, hatchability, and livability of chick. Two hundred and seventy Single Comb White Leghorn pullets were divided into nine equal groups. Each group was confined in a house having a run. The houses were of the same size and similarly constructed. The mash and the scratch grain were the same for each group, except in pens where the chicks received mineral supplement in addition to the mash. The mineral supplements fed included oyster shells in hoppers, raw rock phosphate (8 pounds per 100 pounds of mash), coral sand (8 pounds per 100 pounds of mash), crushed reef coral in hoppers, oyster shells and poultry bone in hoppers, raw rock phosphate (6 pounds per 100 pounds of mash) and poultry bone in hoppers, coral sand (6 pounds per 100 pounds of mash) and poultry bone in hoppers, and crushed reef coral and poultry bone in hoppers. A check lot received no minerals. Records were kept of egg production, fertility, hatchability, mortality, labor expended, and feed consumption.

CANE MOLASSES FOR BABY CHICKS AND FOR LAYING HENS

Three groups each of 189 chicks were fed a mash and scratch ration with varying percentages of molasses as a supplement, and a

check group of 189 chicks received no molasses. Of the first three groups, one received 5 per cent of molasses, the second 7 per cent, and the third 10 per cent. The pullets from each of these groups were fed the same percentages of molasses throughout the first laying year. Records were kept of cost of feed, growth, production, and mortality of fowl, and of the labor expended.

ALL-MASH METHOD OF FEEDING LAYING HENS

An experiment was begun comparing the all-mash method with the mash and scratch method of feeding laying hens. Sixty-six Single Comb White Leghorn pullets on free range were fed a commercial all-mash mixture, and an equal number of Single Comb White Leghorns on free range were fed a commercial mash and scratch mixture. All other management was the same for the two groups. Records were kept on the cost of feed, growth, production, fertility, hatchability, mortality, and of the labor expended. The results obtained were not conclusive, and the experiment will be repeated.

REPORT OF THE SOIL PHYSICS DIVISION

By H. A. Wadsworth

CAPILLARY PHENOMENA IN COLLOIDAL SOILS

During the year a study was made of the factors affecting the rate and height of capillary rise of water through colloidal soils supported over a free-water table. Part of the first year's work, reported here in abstract, dealt with a study of principles. An analogy is often drawn between the capillary rise of water in soils and a similar rise in glass tubes of small diameter. A careful search of the literature of physics failed to disclose studies of the rates of rise of liquids through minute glass tubes. Such studies were therefore undertaken. The equations used in these studies were as follows: $R=K\ (1-e^{-cT})$. Where K and c are constants R=rise in cubic millimeters after T seconds and e=base of natural logarithms.

It is evident that R increases rapidly with T until a critical value for T is reached, beyond which R shows no further increase. In other words, R approaches an asymptotic value. The action is much more complex when carefully screened soils are used. The initial phase of the rise is similar to the form indicated above, but no asymptotic value is reached, the rise continuing long after the term e^{-cT} becomes zero. Consequently, another factor must be taken into account when clean inert sands are used. One hundred and twenty observations were made with five carefully graded sand sizes and a form of expression developed which fits the observed points with surprising precision. The formula may be expressed thus: $R=K\ (1-e^{-cT})T^n$. This formula may be used when the notation is as in the first formula given above, and n equals the natural tangent of the slope caused by plotting logarithmic rise against logarithmic time for values of T larger than that for which e^{-cT} equals zero. The fact that the second phase of the process makes a straight line on logarithmic paper is not an original finding. However, no

attempt has been discovered to analyze the initial phase. The curves from the many observations indicated above are now being evaluated in such a way as to permit identification of significant differences between the several sizes of sands used. Observations at hand indicate that the value of n is independent of grain size. K seems to increase with a reduction in average grain size, whereas c decreases in the same sense. This analysis is complicated by the fact that average grain size alone is not a sufficient criterion for analysis. The range of sizes between the arbitrary limits and the distribution of sizes between them seem to be of great importance. The most important conclusion reached thus far is that capillary rise of water through sands is not a simple, continuous process, but is the result of two actions, each of which follows a different law. The exact nature of these laws has not been determined. Studies with soils emphasize this discontinuity. Here the initial curve seems to degenerate into an initial straight line when plotted logarithmically and a rather sharp point of intersection is provided. This break at once suggests McLaughlin's hump. No satisfactory correlation between these two characteristics has been noted. In fact, many careful observations on the distribution of moisture in columns of local soil fail to disclose an isolated zone of maximum water content, although the moisture distribution is by no means continuous.

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HAWAII AGRICULTURAL EXPERIMENT STATION
HONOLULU, HAWAII

Under the joint supervision of the
UNITED STATES DEPARTMENT OF AGRICULTURE
AND THE UNIVERSITY OF HAWAII

Washington, D. C. April, 1932

REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION, 1931

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SUMMARY OF INVESTIGATIONS

By J. M. WESTGATE, *Director*

During the year covered by this report substantial progress was made in all coordinated activities formerly carried on independently by the Federal station of the United States Department of Agriculture and by the University of Hawaii. Attention was given primarily to problems dealing with minor agricultural crops and with the animal and poultry industries. The latter are growing in importance with the continued increase in the population of the islands.

The availability at the beginning of the year of an additional appropriation of $5,000 enabled the station to make a substantial start with research of a fundamental nature. The station acquired the use of several additional tracts of land for trial plantings at

different elevations and under varying climatic conditions. The work at the Waiakea substation, island of Hawaii, was discontinued, and the equipment was moved to the newly established Kona substation on the western side of the island of Hawaii. Planting operations were begun at Kona in November, 1930.

A 4.2-acre tract of land, adjoining the prisoners' camp near Olinda, island of Maui, where extensive trials with the pigeon pea were begun at an elevation of 3,500 feet, was set aside by an executive order of the governor, dated March 31, 1931, for utilization as a part of the Haleakala substation. Three additional tracts of privately owned land at still higher elevations in the same vicinity were made available for trial plantings of the pigeon pea and other forage crops.

The station, working in cooperation with the Territorial department of forestry, began a series of plantings at the higher elevations of the Territorial forest reserve on the island of Oahu. In every instance the plantings at higher altitudes gave such markedly different results in growth and behavior as to justify devoting considerable time to a study of the various trees, plants, and crops under test there.

Work in agronomy was carried on at the university farm, the Pensacola Street station, and the Haleakala substation, including the four newly acquired experimental tracts at elevations ranging from 3,500 to 6,400 feet, and the tract at the original substation near Makawao, at an elevation of 2,162 feet. In addition to the 591 different varieties, hybrids, and selections of pigeon peas that were under test at the three principal places, 366 new selections were planted. The forms giving the greatest promise of success at the higher elevations were planted along the slopes of Haleakala. These plantings included several selections from the Himalaya Mountains in India. Seed-production studies were continued with 62 different species and varieties of green-manuring crops. Study was made of the effect on seed production of different spacings of the hills in the row and of varying the number of plants in each hill. About 50 species and varieties of economic grasses were tested for use as feed for livestock and to provide a convenient source of propagating material for distribution to dairymen and others. Experiments were continued with many varieties of taro, cassava, sweetpotato, ginger, and edible canna. Plantings were also made of 10 varieties of red peppers and 12 varieties of garden beans.

Work in animal husbandry was primarily concerned with feeding experiments. The seventh year of a test undertaken to determine the effect of feeding sugarcane molasses on milk production and breeding ability in dairy cows was completed. Further study was made to learn the effect of feeding sprouted oats to dairy cows and brood sows, but definite conclusions are not yet available.

Studies of the avocado, the Macadamia nut, and pasture grasses, and fertilizer experiments with coffee, constituted important lines of work in the chemical division. The bitter principle that develops in the avocado when the fruit is heated was isolated and identified. Methods of avocado-oil extraction were further developed, and sterol was successfully isolated from the oil. Studies of the oil content of the avocado were facilitated by the use of the rapid refractometer method of determination. Macadamia nuts were found to vary widely in oil content, a fact that promises to have an

important bearing on future selective-breeding work with the crop. Analytical and fertilizer studies were made with the more promising kinds of pasture grasses on several of the larger ranches. Fertilizer experiments with coffee were begun, and a preliminary coffee-soil survey was undertaken on the island of Hawaii. Miscellaneous analyses were made with a view to solving local problems dealing with fruit preservation, with gardening, and with food composition. Further studies were made of the physical and chemical properties of edible-canna starch.

The horticultural work was concerned principally with methods of propagating and maintaining plantings of tropical fruit and nut trees, and with the establishment of block plantings of the more important economic species in sufficient number to furnish propagating material for fertilizer and cultural experiments. The last line of work mentioned is being carried on preparatory to the establishment of a newly planned economic tropical arboretum by the graduate school of tropical agriculture of the University of Hawaii and the station. Special attention was given to problems dealing with Macadamia, pistachio, and cashew nut trees. Plantings of the more important tropical fruit and nut trees were made at the Kona substation, island of Hawaii, where climatic conditions are different from those at the station in Honolulu. Most of the earlier plantings were made at the latter place. Further attention was centered on the development of various species of Rubus for growth at the higher elevations.

The nutrition laboratory of the home economics division concerned itself primarily with studies of the vitamin content of Chinese cabbage (*Brassica chinensis*), Hawaii-grown oranges, rice-bran bread, and the Hawaii edible shellfish, locally known as "opihi." Some progress was made in a study of the biological value of the protein of the pigeon pea (*Cajanus indicus*). Large, healthy colonies of white rats and guinea pigs were bred for use in the nutritional investigations.

The poultry division continued its studies of the control of sorehead (fowl pox) of baby chicks, giving special attention to the "stick method" of vaccination with "live virus" vaccine. Observations were continued to discover a simple method of readily determining the sex of purebred day-old chicks. Experiments were made comparing the relative merits for chicks of fireless battery and electrically heated battery brooders. No cannibalism was noted when the canopy type of electrically heated brooder was used, but some cannibalism occurred in both the fireless and the electrically heated battery brooders. A test was begun to determine the relative nutritive value of Hawaii-grown papayas, avocados, bananas, and sweetpotatoes as a fattening feed for hens. An experiment was also begun to determine the feeding value of raw cane sugar for baby chicks.

The soil physics division confined its attention to two investigations of fundamental scientific importance. One study was concerned with the factors affecting the rate and magnitude of capillary rise of water and its movement through soils; the other dealt with the correlation of the ratios of the moisture equivalents and the wilting coefficients of a set of economically important soils and the silica sesquioxide ratios of the extracted colloids of the soils.

Over 600 different lots of pigeon peas and numerous grasses, green-manuring and root crops, berries, fruits, and vegetables were under test at the Haleakala substation. Extensive experiments were undertaken to learn the relative efficiency of certain green-manuring crops for pineapple plantations. Pineapple fruits were matured on an experimental plat near Olinda, island of Maui, where the elevation is 3,300 feet. The acclimatization and selective-breeding work with pigeon peas and other forage plants necessitated the establishment of four additional experimental tracts above the substation along the slopes of Haleakala. These tracts are located at elevations of approximately 3,500, 4,800, 5,500, and 6,400 feet. The results obtained at these altitudes will presumably be applicable to about 20,000 acres of range lands on the island of Maui and to extensive areas on the other islands of the group. Cooperation in facilitating the extension work was maintained with the agricultural extension division and with various county agents.

A noteworthy event of the year was the establishment of the Kona substation in the southwestern part of the island of Hawaii. A residence for the superintendent, water tanks, minor buildings, and roadways were constructed, and 2 acres of the 3-acre tract in which the substation is located were cleared and planted with 103 different species, varieties, or strains of economically promising tropical fruit and nut trees or plants. Most of the plantings survived the very severe drought of the year 1930. In addition to growing many plants on the tract, the substation serves as a working center from which a number of outlying experiments can be operated in cooperation with private growers of coffee, grazing grasses, and fruit and nut trees. These experiments are conducted under the general direction of the respective project leaders at the central station in Honolulu, but the substation superintendent keeps in touch with the various lines of work as occasion requires.

REPORT OF THE AGRONOMY DIVISION

By J. M. Westgate, J. S. Low, and M. Takahashi

PIGEON PEAS

Selective-breeding work with the pigeon pea (*Cajanus indicus* constituted the chief activity of the agronomy division. The 591 former plantings were kept under observation, and 366 selections were made for further test and observation, especially of their ability to succeed at the higher elevations where the ordinary forms fail to mature seed. The more promising of these selections were planted on the four new tracts at the Haleakala substation during the year.

GREEN-MANURING CROPS

The experiments on green-manuring crops carried out during the previous year were repeated. An effort was made to determine the effect, especially on yields of seed, of varying the number of plants in each hill. Plantings of the more promising green-manuring crops were made at the university farm and the Pensacola Street station. (Figs. 1, 2, and 3.) These plantings were not duplicated at the

Haleakala substation because in former experiments none of the green-manuring crops bore satisfactorily at the higher elevations.

FORAGE GRASSES

About 50 species of economic grasses are being maintained by the station at the university farm, the Pensacola Street station, or the Haleakala substation. There is a strong demand for the propagating material of these grasses for soiling, grazing, and lawn purposes. Napier or elephant grass (*Pennisetum purpureum*), Merker grass (a form of *P. purpureum*), kikuyu grass (*P. clandestinum*), and Mexican grass (*Ixophorus unisetus*) are the popular grasses. *Stenotaphrum secundatum*, locally known as "buffalo" grass, is in strong demand for lawns where the trees develop too dense a shade

FIGURE 1.—Various species of Crotalarias used in the green-manuring seed production tests

for the growth of the customary lawn grass (*Cynodon dactylon*), locally called "manienie."

ROOT CROPS

Nineteen varieties of Hawaii and Japanese dry-land taro (*Colocasia esculenta*), and 10 varieties of Hawaii wet-land taro were harvested. All the varieties were grown on dry land. The wet-land varieties made as good a showing as did the dry-land varieties and in a few instances outyielded the latter.

Fourteen established varieties of cassava (*Manihot utilissima*) were maintained at the Pensacola Street station—largely to serve as a convenient source of propagating material for farmers desiring to grow cassava as a feed for livestock.

Over 50 kinds of sweetpotatoes (*Ipomoea batatas*), including hybrids and selections, were maintained at the Pensacola Street station. Their desirable qualities are being observed and the more promising kinds will be distributed to growers for further test.

A cultural test was made to determine the comparative yields of rootstocks from small, medium, large, and unassorted pieces of ginger (*Zinziber officinale*) seed stock. Both ordinary and Chinese varieties were used.

FIGURE 2.—*Crotalaria retusa* as a green-manuring crop, heavily loaded with seed

Plantings of edible canna (*Canna edulis*) were maintained at the Pensacola Street station largely to serve as a source of propagating material and also to assure a supply of the different selections and hybrids under test.

OTHER CROPS

Ten varieties of red peppers (*Capsicum annuum*) were obtained through the courtesy of L. N. Bilger, of the University of Hawaii, and planted in a variety and yield test to determine their commercial possibilities.

Tests were continued with the Kentucky Wonder bean and some of its hybrid forms that are proving to be of considerable promise for table purposes. Nine varieties of garden beans, obtained from France in 1928, are being grown for observation and for seed production.

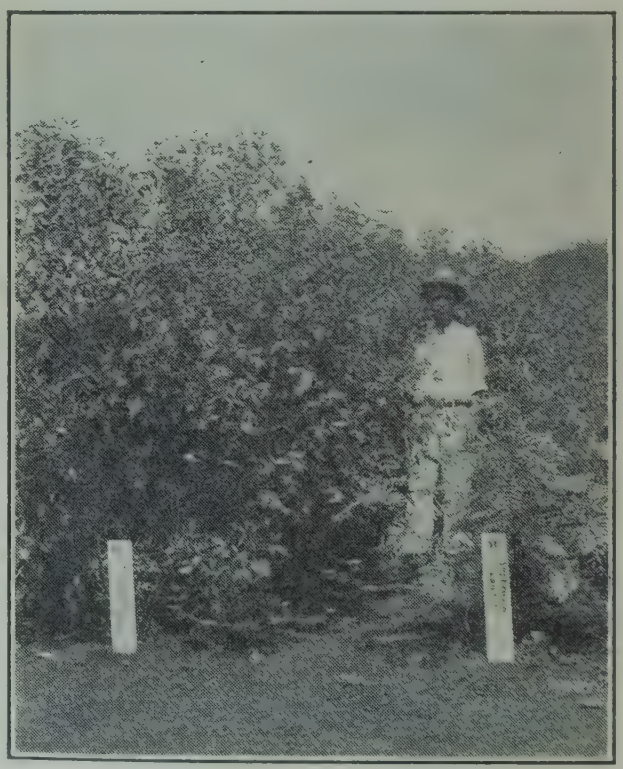

FIGURE 3.—*Crotalaria anagyroides*, a promising green-manuring crop

Of several hundred hybrid forms of lettuce previously under test, five of the most promising were planted for further selection. Four of the latter bred practically true to type. Hybrid No. 1787 is the most promising, the 250 plants showing striking uniformity in such essential characteristics as good heading qualities and freedom from bitterness.

As a basis for future fertilizer and cultural tests with coffee (*Coffea aribica*), preliminary observations are being made of the normal variations in yield of trees in a given block receiving uniform treatment. The individual variation of the trees in yield from year to year is being plotted. In some instances

a tree producing 50 pounds in one year has yielded only about 10 pounds the following year. Such variation in yield from year to year in trees receiving uniform cultural treatment makes it necessary to use great care in attributing variation to differences in the fertilizers applied, or to the methods of pruning and spacing practiced. Observations were continued to determine the relative merit of planting two coffee trees instead of one of the same kind in a place system. In one instance two trees when planted together gave a combined yield of 110 pounds as compared with a yield of 80 pounds from the best individual tree grown singly in the orchard row.

Plantings of four varieties of tobacco (*Nicotiana tabacum*) were made to determine what variation occurs in the nicotine content of the leaves at different stages of maturity. (Fig. 4.) These data will be of value primarily in the contemplated preparation of an insecticide for use in pineapple fields.

FIGURE 4.—Tobacco plants used in testing the nicotine content of the leaves of different varieties

REPORT OF THE ANIMAL HUSBANDRY DIVISION

By L. A. HENKE and M. MANEKI

CATTLE

At the close of the fiscal year the dairy herd numbered, of the Holsteins, 2 bulls, 26 cows, and 16 heifers and calves; and of the Guernseys, 1 bull, 10 cows, and 8 heifers and calves.

Because only about 13 acres of land are available for grazing, soiling crops are grown on the farm and fed throughout the year as roughages to supplement the standard concentrates. The roughages are largely alfalfa, Sudan grass, sorghums, and Napier grass. The dairy herd is stabled only during the milking period, and the other animals are fed in the paddocks. The milking barn and the milk house are modern in construction and equipment. The dairy herd serves the dual purpose of providing animals for use in experiments made by the experiment station and also for instructional purposes for students at the university.

Abortion studies, including agglutination tests by the veterinary division of the board of agriculture and forestry, were continued.

FEEDING RAW ROCK PHOSPHATE

For a period of about 10 years raw rock phosphate has been fed to the dairy herd in amounts ranging from 1 to 1¼ per cent of the concentrate mixture as a protection against mineral deficiency. At no time since the feeding experiment was started have the strikingly

deleterious effects noted at several of the mainland stations been observed here. The rock phosphate, a product of the South Sea Islands, contains less fluorine than does some of the rock phosphate secured in the continental United States. This fact, or the feeding of green forages throughout the year as is the local practice, may influence the results.

FEEDING A RATION CONTAINING SUGARCANE MOLASSES

Sugarcane molasses is both plentiful and cheap in Hawaii and may make a desirable feed for dairy cattle because of the relatively high cost of the imported concentrates. An experiment in which cows are fed a concentrate mixture containing 25 per cent of sugarcane molasses is now at the end of its seventh year at the station and will be continued for another year or two to obtain additional information on the effect on milk yield and reproduction. Results to date, while not complete, suggest that 25 per cent of sugarcane molasses in the ration may be somewhat too high for best results in both milk yield and breeding.

FEEDING SPROUTED OATS TO BREEDING DAIRY COWS

According to Winters (*8*),[1] the thought that sprouted oats, because of the abundance of vitamin E it contains, might be of value in overcoming temporary sterility in dairy cows, when the sterility is not due to pathological or other abnormal condition, originated with Herbert M. Evans, of the University of California. Graves (*4*, *p. 17*), of the Bureau of Dairy Industry of the United States Department of Agriculture, also carried on some work along this line, and others made observations (*1*, *p. 7*) at various commercial dairies to learn the effect of feeding sprouted oats to dairy cattle as a remedy for sterility. In the present experiment sprouted oats is fed to every alternate cow or heifer that exhibits any irregularity in breeding behavior, such as failure to show the normal oestral cycle or to conceive after being bred. The cows not otherwise under test are used as a control group. To date 18 cows and heifers have been or are being fed, and there is an equal number of animals in the control group, but it is too soon to draw definite conclusions. Results thus far, however, are not especially favorable to sprouted oats as a remedy for temporary sterility in dairy cows.

SWINE

Included in the swine herd at the close of the fiscal year were 11 Tamworth and 5 Berkshire breeding animals and 37 smaller pigs. These are used for study by men specializing in animal husbandry and for experiments undertaken by the station. The buildings used for the swine consist of one central piggery with concrete feeding pens, feed-storage room, and scale room, and there are portable hog houses in outside paddocks.

FEEDING SPROUTED OATS TO BROOD SOWS

Sprouted oats are fed at the rate of 1 pound daily, dry basis, per animal, to every sow or gilt that exhibits abnormal breeding behavior.

[1] Italic numbers in parentheses refer to Literature Cited, p. 38.

The alternate sows not receiving sprouted oats are used as a control group. To date six sows or gilts have been, or are being fed the oats, and an equal number of animals are used as controls. The experiment has not progressed sufficiently far to justify drawing definite conclusions.

FEEDING RAW SUGAR

Palatability is an important factor in animal nutrition; and since increased consumption usually results in more economical gains in body weight, the use of raw sugar at its present low price as a means of increasing palatability seemed practical. A mixture consisting of 88 pounds of barley, 8 pounds of tankage, 2 pounds of linseed oil-cake meal, 1 pound of steamed bone meal, and 1 pound of salt was fed to the hogs in the control group. In the sugar ration 5 per cent of raw sugar was used to replace an equal weight of barley in the control ration, and in a third ration 10 per cent of raw sugar was substituted for a like amount of barley. Eighteen hogs were used in each experiment, 6 in each lot, and the experiment was replicated three times, using a total of 54 hogs. In practically all instances faster and more economical gains resulted from the addition of raw sugar to the ration.

REPORT OF THE CHEMICAL DIVISION

By J. C. Ripperton and D. W. Edwards

MACADAMIA NUT

Twelve representative 8-year-old seedling trees of the smooth-shelled variety of Macadamia nut in a local orchard were selected for study throughout the year. The nuts from each tree were accumulated for a month, at the end of which time the total weight from each tree was determined and a 2-pound sample was taken for analysis. After being allowed to dry for one month, the samples were subjected to the various methods of study developed to determine the oil content, the proportion of culls, and the cracking and roasting qualities. The largest annual yield per tree was 65 pounds of husked nuts, and the lowest 36 pounds. The kernel yield of the best tree was 40 per cent and of the poorest 21 per cent. The high oil content noted in previous experiments persisted in all the trees. Ninety-eight per cent of the nuts from the best trees contained 70 per cent or more of oil, whereas from the poorest tree 85 per cent of the nuts contained 70 per cent or more of oil. A small number of nuts fall from most Macadamia trees throughout the year, but the main crop falls during a period of about three months. The nuts falling before and after the main crop are likely to be subnormal in quality.

Work was continued on methods of grading nuts both for factory use and for planting. Improvement was made in the technic of determining the oil content of the nut by means of the refractometer and by the specific-gravity method. The latter is accurate to within plus or minus five-tenths of 1 per cent and is especially valuable for the study of individual nuts or for dividing nuts according to oil content. A score card was developed for scoring Macadamia nuts, patterned after methods used in scoring other commercial nuts. On

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the basis of 100, proportion of kernel is scored as 40, size of kernel as 20, packing appearance as 10, and cracking quality as 30.

One sample of nuts from each of 11 trees located in different parts of the islands was graded and scored. Extreme variation occurred in the different properties of the nuts. Under the method of scoring described above, the variation in the score ranged from 42 to 97. Bitter nuts were found on three trees. These are being investigated to learn whether the bitter principle is inherent or due to the adsorption of tannin from the husk.

SOIL INVESTIGATIONS

SURVEY OF THE KONA DISTRICT

The chemical division working in cooperation with the geologist of the Volcano Observatory, United States Geological Survey, made a soil survey of the Kona district of the island of Hawaii. This district is geologically very young. The massive rock formation has shown practically no disintegration. The soil is derived almost wholly from the scoria of a-a lava flows and from volcanic ash. The type of underlying lava and the varying amounts of ash and scoria form a logical basis for classification of the soils and division of the district into definite soil areas. Plans are under way to correlate the soil types with coffee production and fertility. It is believed that the soil map which is being prepared will be of value not only in a study of the present agriculture of the district but also in forming a basis for outlining the Kona areas of potential importance for extension of the coffee and other agricultural crops.

RELATION OF TYPE TO PARENT MATERIAL

It is a question whether the lava types of the Hawaiian Islands are sufficiently different to give rise to differences in soil type, especially on the older islands of the group where many of the soils are approaching the lateritic stage. There is, however, a very pronounced difference in the nature of the soils derived from volcanic ash and from lava. The former have received little study because of their occurrence largely on the upper mountain slopes. During the year a series of soil samples for analyses were collected from the principal ash areas of the island of Hawaii. Preliminary analyses showed great differences in physical properties, particularly with respect to hydration. Certain of the highly hydrated types when air-dried could not be dispersed even on prolonged shaking and stirring. Samples of these soils should be taken moist and preserved in air-tight containers. It is planned to continue the study of the physical and chemical characteristics of these ash soils.

COFFEE

REJUVENATION OF OLD PLANTINGS

Experiments, begun in 1929, to determine the best method of renewing old coffee plantings in the Hamakua region, island of Hawaii, were continued. Each plant receives the standard amount of complete fertilizer in October, one application of sodium nitrate in January and another in March. The heavily pruned and the

thinned plats show excellent new growth. (Fig. 5.) Unfortunately much pruning is required to thin out the excess of new growth. New uprights have developed on practically all the trees of which the trunks were cut off 1 foot above ground to induce new top growth. The growth of seedlings has been somewhat retarded by dry weather during their first year.

FERTILIZER EXPERIMENTS IN KONA

Two fertilizer experiments with coffee were begun during the year, one in the Kainaliu region and the other in the Kealakekua region. The plantings are 4 and 6 years old, respectively, and are set in 50 plats (25 at each place) of 9 trees each, spaced 9 by 9 feet.

FIGURE 5.—Rejuvenation of coffee plantings 20 years old. Severely pruned plants showing the vigorous new lateral growth six months later

Field experiments with coffee in the Kona district present unusual difficulties in soil, topography, and plant. (Fig. 6.) Under the type of pruning practiced in Kona the trees, particularly the younger ones, are in different stages of development each year. The experiment in Kealakekua is designed primarily to permit study of the effect of these factors on the magnitude of the annual and the interplat variation. All trees in the experiment are receiving uniform fertilizer and cultural treatment. Growth notes are being taken semiannually to correlate variation in yield with growth characteristics. The yield of coffee cherries per plat is being determined. It is planned to continue using the uniform fertilizer treatment until such time as a definite yield value can be assigned to each plat, when different fertilizer treatments will be begun.

The Kainaliu plats appear to be very uniform in soil and in tree growth, and the preliminary period used in the experiment at Kealakekua is being dispensed with at Kainaliu. Four different fertilizer treatments are being used: Nitrogen alone, nitrogen and potash, nitrogen and phosphorus, and complete fertilizer. The four treatments, together with a check, are replicated five times (25 plats in all). Growth notes are being taken and plat yields of coffee cherries recorded. Ditches have been dug between the plats to prevent border trees from using fertilizer from adjoining plats. This ditch was considered to be more desirable than the usual check row, because of the small size of the field available and the greater variability resulting from increasing the distance between plats.

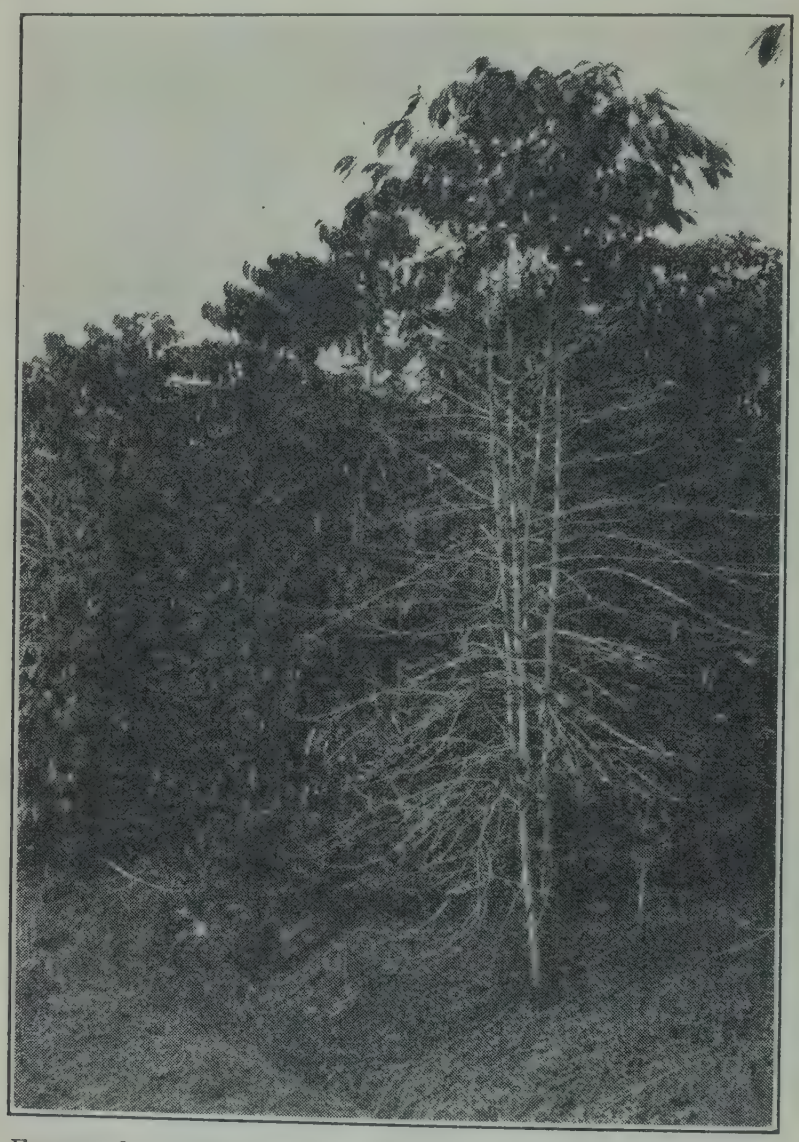

FIGURE 6.—Difference in growth cycles of coffee trees is an important cause of variation in yields from fertilized plats in Kona. The middle and lower sections of the tree in the foreground are bare of fruiting laterals, because of overbearing and the dry weather that prevailed during the year. This tree will yield very little during the coming year, whereas the trees in the background will make a good yield. The following year these conditions may be reversed

GRASSES

MINERAL COMPOSITION

Work was begun in determining the mineral composition of the pasture grasses in the more important ranching areas on Hawaii. Experimental plats were eslished on the Parker ranch at four places, viz, Kamuela, Waiki, Keamoku, and Puukapu Tract No. 2; on the Von Holt ranch in Kohala, the Hind ranch in Puuwaawaa, the Greenwell ranch in Kealakekua, the Kapapala ranch at Kapapala and at Ohaikea, and the Shipman ranch at the Volcano and in Waipahoehoe. Each experiment occupies a tract 30 feet by 20 feet. Half of each tract receives fertilizer applications at the rate of 1,000 pounds of limestone, 300 pounds of superphosphate, and 100 pounds of potassium sulphate per acre. A wire cage, or quadrat, 6 feet wide by 9 feet long by 3 feet high (fig. 7) is placed so that half of it rests on the fertilized strip and the other half on the unfertilized strip. The purpose

of the fertilized and unfertilized strips outside the quadrat is to make possible the determination of differences in palatability and changes in grass population under actual grazing conditions. The area in the quadrat is to be cut at intervals of two months throughout the year. Fertilized and unfertilized samples from each strip will be sent to the central station in Honolulu for determination of their nutritive constituents and for analyses for calcium and phosphorus. The grass in each quadrat has been restricted as much as possible to one species or to similar different species. The nongrass growth will be separated from the grass samples before the analyses are made. An annual botanical count will be made of the principal

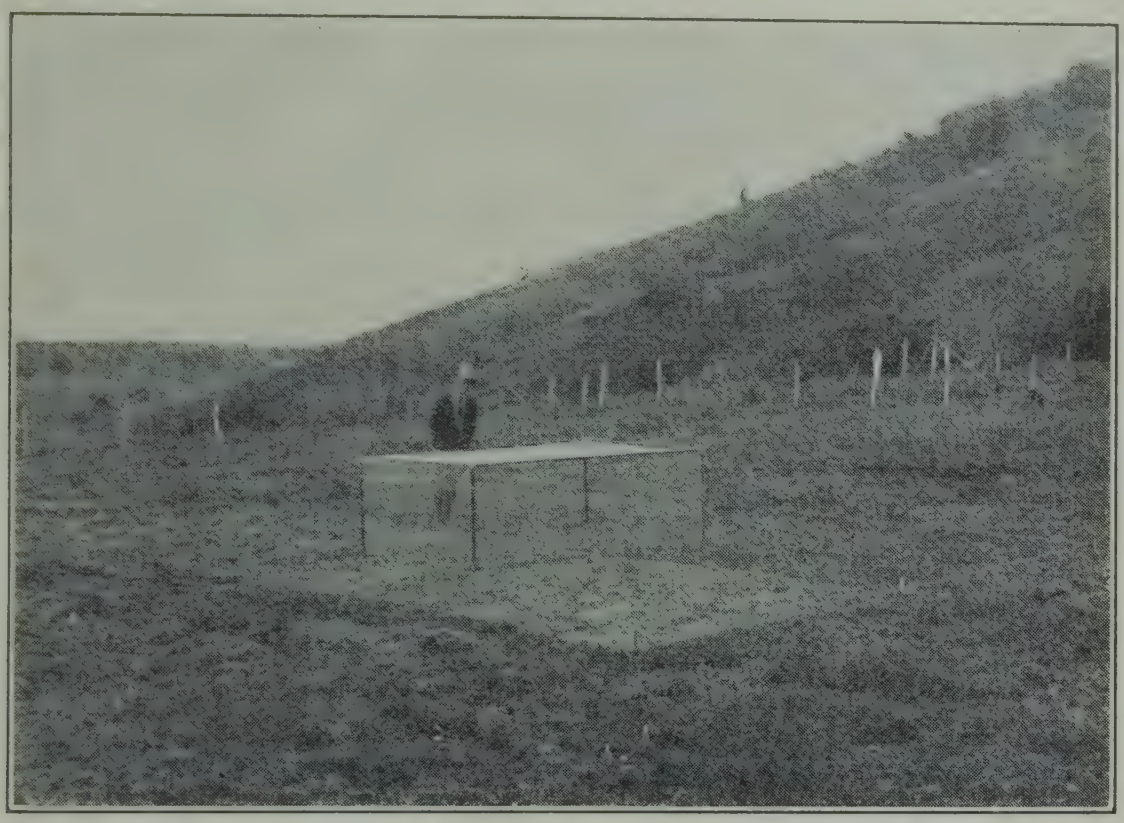

FIGURE 7.—Quadrat method of studying the mineral composition of grasses. The strip on the lower side has been fertilized, whereas that on the mountain side serves as a check. The wire cage (quadrat) is placed so that half of it rests on the fertilized strip and the other half on the unfertilized strip. Samples of grass for analysis are cut from each half at bimonthly intervals

grass species found in the fertilized and unfertilized strips to learn what changes in grass population the fertilizer causes.

PRINCIPAL SPECIES IN HAWAII

Sixty-five different kinds of grasses, legumes, and herbaceous plants were collected from the cattle ranges on Hawaii. Each was photographed to show how it grew under field conditions. Eighty samples of grasses were analyzed for determination of their chief organic and mineral constituents. The chemical division, working in cooperation with the local agricultural extension division, recorded the opinions of various ranchers regarding each grass.

STARCHES

Previous investigations showed that the cations present in a starch bear an important relation to its properties. Analyses were made of

the total potassium, sodium, calcium, magnesium, and phosphorus in a series of 45 starches, including commercial samples of potato, edible-canna, corn, wheat, and cassava starch. Work was begun to learn whether the cations differ in their degree of replaceability. Viscosity and swelling power of the starches are also being determined.

MISCELLANEOUS ANALYSES

Numerous samples of brackish irrigation water and of garden soil were analyzed in connection with the local gardening industry. Nutritive and mineral analyses of 10 of the more commonly used oriental foods were made. The refractometer method of determining the oil content of avocados was studied as a means of aiding the local avocado industry. This method permits the determining of the oil content in about 30 minutes. Several local varieties of avocados, picked at different stages of ripeness, were analyzed.

REPORT ON SPECIAL AVOCADO CHEMICAL INVESTIGATIONS

By Leonora N. Bilger, W. Y. Young, and Ruth C. Robbins

In addition to the experimental work done, an historical review was prepared dealing with problems of avocado preservation, bitter substances of plant origin, and the nature of tannins and their detection in the fruit, and a bibliography of the literature concerning the avocado was compiled.

ISOLATING THE BITTER PRINCIPLE

The experimental work resulted in the isolation, study of properties, and determination of the chemical composition, molecular weight, and formula of avocado tannin. The procedure in the isolation of the tannin was as follows: About 1,600 grams of fresh seeds were sliced into boiling 95 per cent alcohol, removed after being allowed to boil for a few minutes, dried, and ground fine enough to pass through a 20-mesh sieve. The pulverized material was extracted with 50 per cent alcohol until the solvent became clear. The 95 per cent alcohol used for sterilizing the material was diluted and further used for completing the extraction. The alcohol solution was strained through cheesecloth, filtered again, and extracted in a separatory funnel with a 50:50 alcohol and ethyl acetate mixture that had been saturated with salt. The alcohol-ethyl acetate extract was then evaporated to dryness in vacuo, and the residue was treated with water and filtered. The clear filtrate was saturated with salt and extracted with pure ethyl acetate. The extract was again reduced to dryness under low pressure, dissolved in 20 cubic centimeters of distilled water, extracted several times with pure ether to remove fats and other impurities, and finally extracted with ethyl acetate. Salt was added to saturate the water layer. The ethyl acetate-salt treatment was repeated twice, and the aqueous solution was finally extracted with pure ethyl acetate.

Ethyl acetate of the greatest purity was used for the extraction. In view of the fact that the tannin is comparatively more soluble in water than in the acetate, the extraction was repeated fifteen times, 10 to 15 cubic centimeters of solvent being used each time.

The aqueous layer gradually became lighter in color and was roughly tested from time to time to determine the amount of dissolved tannin it contained. The extraction was continued until only a negligible amount of tannin was indicated with ferric chloride.

The final ethyl acetate extract was evaporated in a vacuum distillation apparatus to about 20 cubic centimeters. Evaporation to dryness was completed in a vacuum desiccator after the concentrated extract was transferred to a suitable crystallizing dish. The evaporation was hastened by warming the dish to about 60° C. before placing it in the desiccator. Toward the end of the evaporation, the vacuum was carefully regulated so as to prevent too rapid boiling and foaming of the sirupy residue.

To remove the last traces of ethyl acetate, fats, resins, and other impurities of a similar nature, the residue was washed several times with pure anhydrous ether in which the tannin is practically insoluble. After the product was again evaporated to dryness it was transferred to a vacuum desiccator and completely freed from the ether. The pure product weighed 4.36 grams, representing 0.07 per cent of tannin, calculated on the dry basis. The final product was friable and crisp, of a light tan color that darkened on exposure to light and air, completely soluble in water, alcohol, ethyl acetate, and acetone, and insoluble in ether, chloroform, and benzene. The taste was bitter and astringent, and no odor was detected. The absence of glucosides of the ordinary type and of alkaloids was established.

It is well known that the bitter taste is often absent until certain substances present undergo simple changes, such as hydrolysis. The study of the behavior of avocado tannin led to the conclusion that the hydrolysis of tannins causes the bitter taste noted when the avocado is heated under various conditions. Ethylene treatment of the avocado was begun with a view to removing the tannins, the methods developed by Harvey (*5*) being used for the purpose.

STEROL CONTENT AND VITAMIN VALUE OF AVOCADO OIL

The customary methods of oil extraction when applied to the avocado gave low yields, due apparently to the tight cell structure of the fruit. These methods included (1) mechanical pressing, (2) trying out the oil at about 75° C., (3) prolonged boiling with water and collecting the oily layer, (4) extracting with ether in a Soxhlet apparatus, for which purpose fresh material, dried material, rotted material, and rotted and dried material were used, and (5) centrifuging the mashed rotted pulp to throw out the oil. Of these methods, mechanical pressure and ether extraction proved to be the most satisfactory. The pressure method, however, resulted in a low yield and required subsequent purification of the oil. The extraction method gave a fairly good yield, but required too much time and a relatively large amount of ether.

Under the method finally developed the ripe avocados were washed, peeled, and frozen for about 24 hours in an electrical refrigerator at a temperature of −4° C. They were then covered with a thin layer of water and melted on a water bath at a temperature of about 75° C. Alternate freezing and melting were repeated three times. The warm material was placed in 50-cubic centimeter centrifuge tubes and cen-

trifuged for five minutes at the rate of about 1,800 revolutions per minute. As a result the oil and the avocado mass packed at the top of the tubes and the water collected at the bottom. The water was poured off by making a channel between the avocado mass and the side of the tube with a narrow spatula. The tubes and the contents were warmed in a water bath, and centrifuging was repeated for 15 minutes. A clear, yellow oil collected on the top of the solid mass. This oil was removed immediately so as to prevent it from becoming distributed through the solid material. If additional water collected, it was removed and centrifuging was repeated.

From 20 to 30 cubic centimeters of ethyl ether were added to the solid material left in each tube, and the whole was thoroughly mixed and centrifuged for 15 minutes. The ether solution of the oil was transferred to a distillation flask immediately. Treating with ether and centrifuging were repeated on the solid material remaining in the tubes. The new extract of oil was added to the first quantity. The ether was removed by distillation over a water bath. A 10 per cent yield of clear, yellow oil was obtained. The comparatively large yield of oil, its purity and comparative freedom from rancidity, and the simplicity of the procedure offer distinct advantages over the results obtained by the other methods described. It is easily adapted to large-scale extraction. This work is to be continued with a view to establishing the chemical nature of the sterols and their nutritive value. Since certain vitamins are thought to be sterols, it is desired to determine whether avocado sterols are vitamins or have vitamin value. Study will be made by animal experimentation.

The avocado oil obtained by the method above described was used to isolate the sterol. Fifty grams of oil were placed in a 1-liter flat-bottomed flask connected with a reflux condenser and with a round-bottomed 700-cubic centimeter flask containing 400 cubic centimeters of aldehyde-free 95 per cent alcohol. This alcohol was prepared by distillation with *p*-phenylenediamine hydrochloride and tested for aldehydes by reduction of silver nitrate. The two flasks were placed on a water bath, and the alcohol was distilled through the warm oil, being refluxed and collected in a layer on top of the oil. This alcohol layer was replaced in the round-bottomed flask and the alcohol distilled through the oil again, leaving about 100 cubic centimeters of alcohol to contain the sterol dissolved out of the oil by the first extraction. This process was repeated three times, by which time most of the sterol content of the oil had been transferred to the alcohol solution. The alcohol solution was then evaporated to 250 cubic centimeters, and 20 cubic centimeters of 1-to-1 potassium hydroxide were added to the hot alcohol when the mixture was boiled for 10 minutes. This was then added to 500 cubic centimeters of warm ether in a large separatory funnel and thoroughly mixed, care being taken not to permit the formation of an emulsion.

Three hundred cubic centimeters of water were then added, and the alcohol-soap-water layer was drawn off. The ether was washed with water until free from soap. The ether solution of the sterol was evaporated to 25 cubic centimeters, placed in a 50-cubic centimeter beaker, and evaporated to dryness on a water bath. A yellow residue resulted. Five cubic centimeters of acetic anhydride were added, and the mixture was heated to boiling for a few minutes over

a free flame. The mixture was cooled, and 35 cubic centimeters of 60 per cent alcohol by volume were added. A white precipitate which resulted was filtered off and washed with 60 per cent alcohol. The precipitate was dissolved in a stream of hot 80 per cent alcohol by volume, collected in a small flask, and placed in the ice chest at 12° C. The sterol crystallized out in small white crystals. These were recrystallized from hot absolute alcohol and allowed to evaporate in a small weighing bottle. The weight of the product was obtained after being allowed to dry for one hour at 100° C. This material was used to determine the melting point.

REPORT OF THE HORTICULTURAL DIVISION

By W. T. Pope

PROPAGATION OF TROPICAL FRUITS AND NUTS

Throughout the Hawaiian Islands there are large numbers of species and varieties of tropical and subtropical fruit plants of considerable economic value. Many of them are grown to a small extent, and the best methods of their propagation and culture are not well understood. The horticultural division devoted part of its time to an investigation of the possibilities of these plants and to the development of suitable methods of propagating them. Similar studies were made of certain economic plants that are new to the Hawaiian Islands.

The numerous plants propagated during the year included the litchi (*Litchi chinensis*), mabolo (*Diospyros discolor*), Ceylon olive (*Elaeocarpus serratus*), Australian rednut (*Hicksbeachia pinnatifolia*), cashew nut (*Anacardium occidentale*), mamey sapote or sapodilla (*Achras zapote*), egg fruit (*Lucuma obovata*), water apple (*Eugenia aquea*, a station hybrid), coffee (*Coffea arabica* and *C. robusta*), tung-oil tree (*Aleurites fordii*), cacao (*Theobroma cacao*), horseradish-tree (*Moringa oleifera*), sapucaia nut (*Lecythis zabucajo*), cohune nut (*Attalea cohune*), and the pili nut (*Canarium ovatum*).

MAMEY APPLE

Seed-germination experiments were in progress with the mamey apple (*Mammea americana*). The seeds were sown in clean coral-sand mediums and in a light humus soil. The best results were obtained from the use of the coral sand. The medium, however, was found to be less important than the removal of the seed coat immediately before the seed is planted. Seeds so treated germinated in a few days, whereas those not having their tough, thick seed coats removed required from five weeks to several months in which to germinate. This tropical American fruit has been only sparingly grown in Hawaii for many years. Recently, however, trees producing unusually good fruit have attracted attention. Good varieties are reported to have been established in the West Indies through vegetative propagation by inarching. It has also been observed that neither the tree nor the fruit is attacked by such insects as are commonly destructive to many fruits in Hawaii.

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BREADFRUIT

Propagating material, consisting of cuttings taken from the surface roots, of Samoan seedless breadfruit trees were received for trial in December, 1930. This material made over two hundred 5-inch root cuttings ranging from 1 inch to 1¾ inches in diameter. The cuttings were sprouted in the propagating house in a bench about 10 inches deep. A 2-inch layer of rich garden soil was spread in the bottom of the bench and overlaid with an 8-inch layer of coral sand. The cuttings were placed horizontally 2 to 3 inches apart about 2 inches below the surface of the sand, which was then slightly firmed and watered daily. After six months this method of propagation has given a fair percentage of plants of suitable size for potting in gallon containers. After making further growth the plants will be transplanted to permanent place in the ground. (Figs. 8 and 9.) Seedless breadfruit has been propagated by this method at the station for several years in cooperation with G. P. Wilder. Mr. Wilder has introduced breadfruit varieties from other tropical Pacific islands for trial in Hawaii.

FIGURE 8.—Plants of the seedless breadfruit tree propagated from piece-root cuttings. No. 1 is from a cutting that was buried horizontally in coral sand, and No. 2 is from a cutting that was rooted in upright position with the top exposed above the sand

PANAMA BERRY TREE

The Panama berry tree (*Muntingia calabura*) (No. 4768) [2] is a native of tropical America and may be of value in Hawaii. (Fig. 10.) Some half a dozen of the trees were introduced at the station for the first time on July 26, 1922. They did not attract attention, however, until they began to bear fruit during the last two or three years. The tree is remarkable for the abundance of very small seeds in the pulp of the edible fruit. Germination is effected (1) by

[2] Number under which plants were received at the station.

drying the fruit, cutting it into very small pieces containing the seeds, and planting them in fine, sifted soil; and (2) by squeezing the seed-laden juice on to a firmed surface of sifted soil that is topped with a light, thin covering of pith of the coconut finely grated. Optimum moisture conditions are maintained by allowing water to soak into the ground from below or from one side of the plantings.

CERIMAN

The ceriman (*Monstera deliciosa*) is a tropical American climber of early introduction into Hawaii. It is grown to some extent on rock-work and on tree trunks as an ornamental. When grown in the open it is spreading in form and increases in prolificacy. The edible fruit

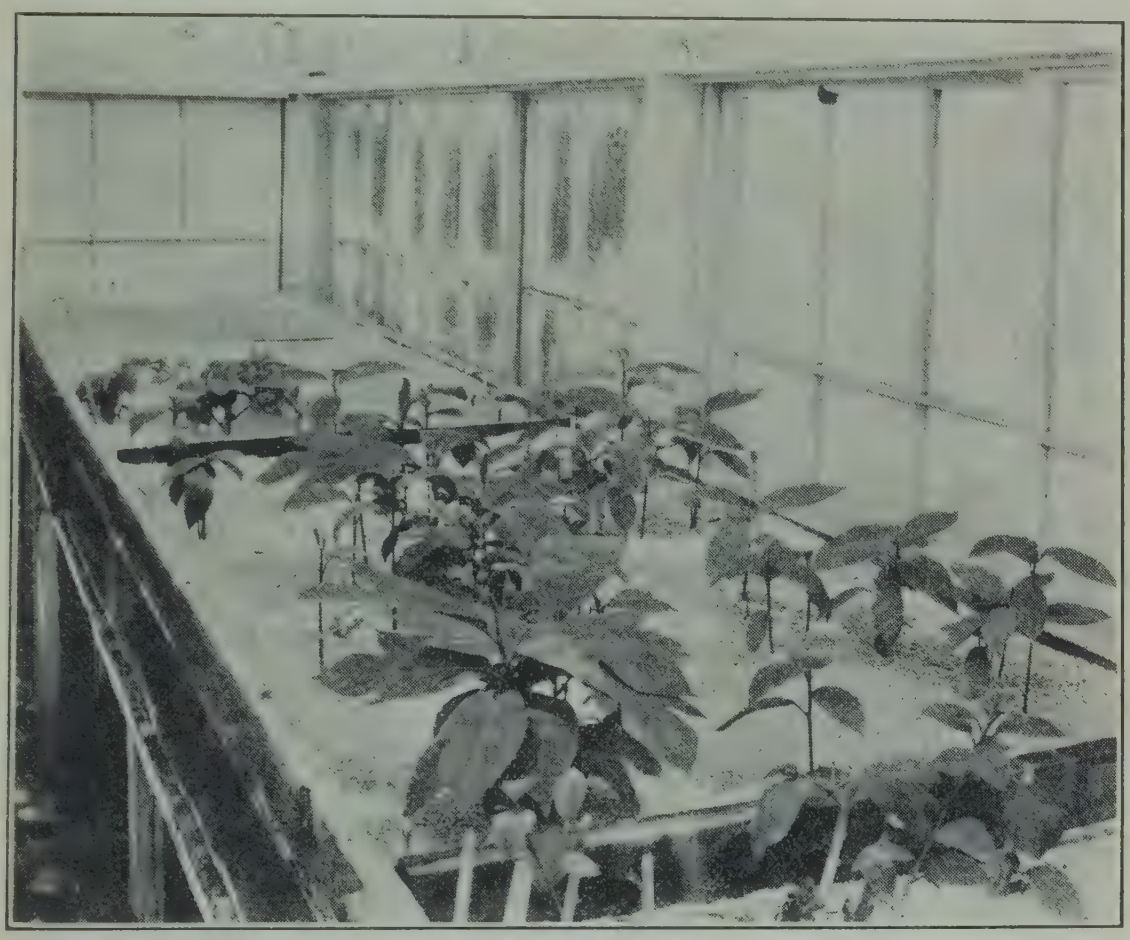

FIGURE 9.—Propagating bed of seedless breadfruit plants developed from root cuttings

has a pleasing flavor which is somewhat like that of the pineapple. The ceriman is easily propagated from cuttings of the mature stems. Each cutting should contain several nodes and the cuttings root best when half buried horizontally in rich sandy loam. The ripe fruit occasionally contains a few seeds near the base. These germinate easily in sand or in light soil. (Fig. 11.)

MACADAMIA NUT

Macadamia-nut investigations have been in progress at the station for several years. The unusual interest taken in growing this tree commercially indicates the importance of giving further study to its habits of variation, vegetative methods of propagation, and general cultural requirements. The investigations have been made

at the station and in the orchards of private growers. The tree exhibits many variations both in time of blooming and in nature of blossoms. It blooms mainly in April but may bloom a few weeks

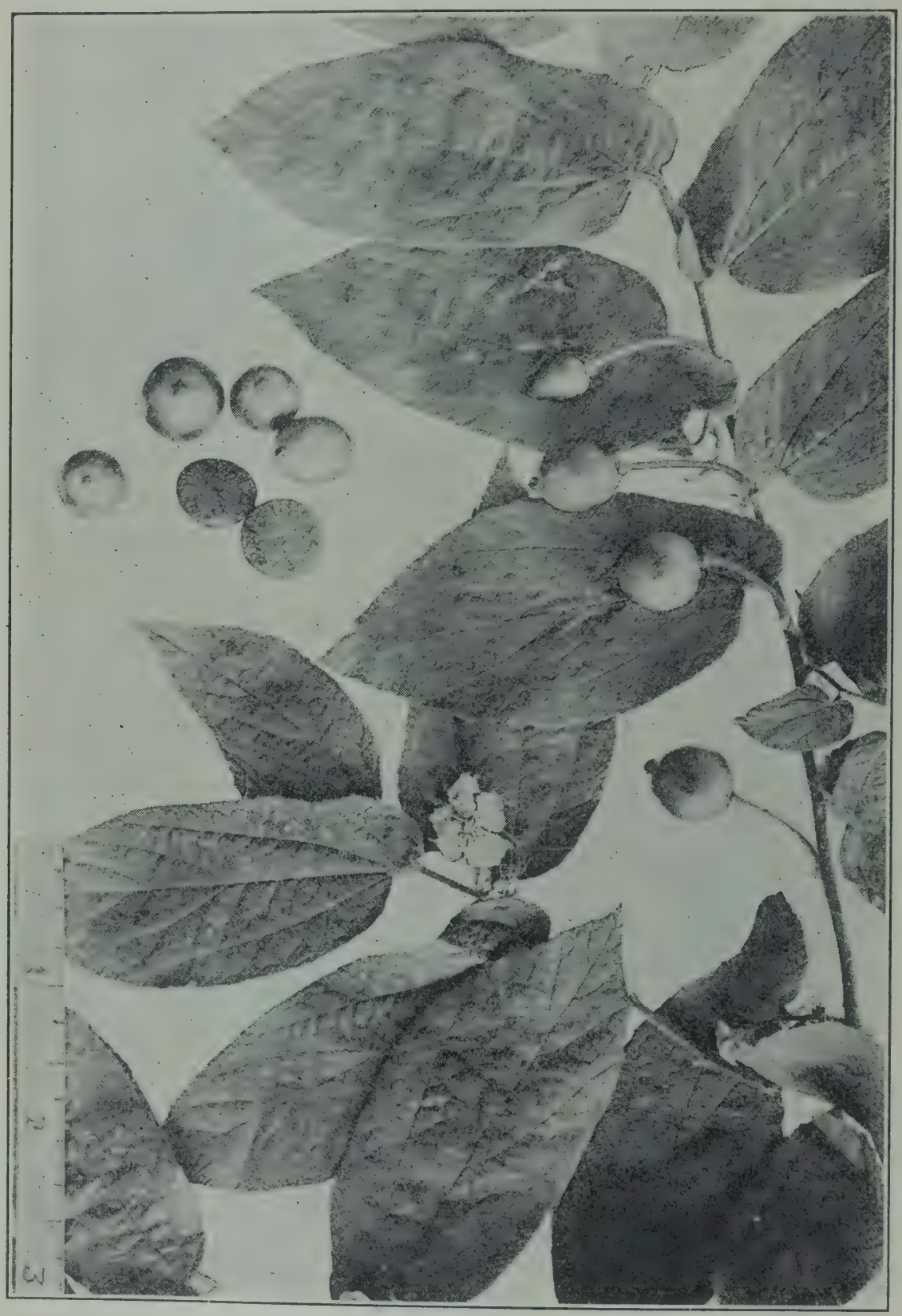

FIGURE 10.—Panama berry (*Muntingia calabura*). The fruit of this tropical American tree is of pleasing flavor

earlier or later. The time of blooming is possibly influenced by immediate local climatic and soil conditions. Trees are commonly found which bloom continuously and mature nuts during the greater part of the year, but they produce no large crops in any one period.

Some Macadamia trees have two blossoming periods and two crop-maturing periods. These are in the spring and in the fall. Nuts resulting from the spring blossoms mature about the time the fall blossoms are due, or just before. Most Macadamia trees, however,

FIGURE 11.—Ceriman (*Monstera deliciosa*) grown from a cutting. It is about 7 years old and has been fruiting freely for several years

bloom heavily in the spring and mature their crop in the fall. This condition is the one preferred by most commercial growers. It is believed that a regular season of bearing can be controlled by use of vegetative propagation and cultural methods.

In observations on variation in inflorescence of different seedling trees it was found that in an orchard of 60 seedlings about half the trees bore white or cream-colored flowers, whereas the rest were of pinkish and reddish shades. Color of flower does not appear to be correlated with quality of nut. Individual catkins vary in length and in number of flowerets. Catkins average about 12 inches in length, although a number of them were found during the year to measure from 18 to 22 inches. The flowerets often number several hundred per catkin. Most of them are shed naturally during the latter part of the blooming period. Many that do set are shed as small nuts during their early growth. The trees naturally retain as many as they are able to bear to maturity. The number of nuts matured to a catkin ranges ordinarily from 1 to 12. Some catkins were found with 20 or more to the cluster, and several had more than 100 nuts to a cluster.

FIGURE 12.—Macadamia-nut tree in bloom. The flowers are borne on long catkins which give the tree a beautiful appearance

Large numbers of seedling trees bear heavily at the proper age, which is about 12 years. These habits of bearing may be perpetuated by using vegetative methods of propagation for the establishment of trees on a commercial basis. (Fig. 12.) During the fall of 1930 a study was made of the variation of nuts of different seedling trees. More than 50 per cent of the trees examined produced nuts undesirable for commercial use, being too small, thick-shelled, rough-surfaced, irregular in shape, or of poor flavor. Rooting the cuttings has not been satisfactorily practiced as a method of propagation. Top-grafting 1-year-old or 2-year-old seedlings in permanent place has been a success under some unusually moist conditions.

New seed was obtained from several sources. Some large spherical nuts were obtained from Australia through cooperative exchange. These were germinated and the resulting seedlings planted in the experimental plat at the Kona substation. Medium-sized, thin-shelled nuts were also obtained and are being propagated.

AKALA OR NATIVE RASPBERRY AND OTHER SPECIES OF RUBUS

During the first week in April, 1931, the horticulturist made a trip to Mount Hualalai, island of Hawaii, for the purpose of studying the akala plants growing there. One species of akala (*Rubus hawaiiensis*) forms the greater part of the undergrowth in what is considered to be the timber-line region, where the elevation is about 6,000 feet. In many places the plants were in fruit. (Fig. 13.)

FIGURE 13.—Akala plants spreading in the open woods of the forest reserve, Hualalai. After cattle were shut out for 2½ years the akala plants began to form a large portion of the necessary undergrowth for the natural forest. Elevation of this part of the forest reserve is about 6,000 feet. (Photographed April 11, 1931)

Ripe fruit has been collected by the forest ranger as early as April 1. In some places another species (*R. macraei*) was found growing among these upright plants. The plants are prostrate and roving in habit and do not blossom until late in the summer in this part of Hawaii, and the fruits, which are rather large, ripen during late August and early September. Sprouting root clumps were dug up with the rich soil adhering to the roots and packed in paper and burlap for shipment to the central station in Honolulu. Eighteen clumps, nine plants of each of the two species, were brought down the mountain by pack mule 9 miles to Holualoa, whence they were transported by automobile to the Kona substation and thence shipped to Honolulu. During the following week they were set out on the mountains of Oahu, where the elevation ranges from 2,200 feet to 3,700 feet. It is hoped that these two species will become

established and widely spread from seeds dropped by birds, as was the case on the island of Hawaii. It is believed that their success on Oahu will aid in the work of adapting them to the lower elevations.

The propagation of Rubus species, particularly the raspberry, is difficult. None of the species thrives at the lower elevations in these islands. Seed of most of the species tried has failed to germinate. With possibly one exception this was found to be true of the wild native raspberry, or akala, that grows on the upper forest reserves. Seeds of *Rubus hawaiiensis* were obtained from different localities in July, 1930, and again in April, 1931. Some of these seeds were brought to the central station in the fruit, others had been removed from the fruit and after being allowed to dry for a few days were planted, and a third lot was mixed with a quantity of humus from the forest in which the plants grew. The first two lots were divided into two groups each and placed for germination in coral sand and in light soil mediums. The humus containing the seeds of the third lot was used as a surface layer on one portion of sand and on soil prepared in the germinating flats. Although the seeds had been planted two months before, they had not germinated June 30, 1931. Plants of both *R. hawaiiensis* and *R. macraei* were removed with the soil adhering to the roots, from their natural habitat on Hawaii, where the elevation is 6,000 feet, and transplanted on Oahu, where the elevations range from 2,200 to 3,700 feet. Opportunity for experimental work with them is better on Oahu than on Hawaii. Both species have some very promising characters. Seeds of a wild species of Rubus with edible fruit were recently introduced into Hawaii from Java by the station. The dried seeds were soaked in water for several hours before they were planted and gave a high percentage of germination a few days later.

Most of the varieties introduced from the mainland of the United States failed to grow well in any of the trials made at the different elevations. More than half of the introduced 19 varieties died. The varieties making the best growth included dewberries, blackberries, and a Philippine species of raspberry. In December, 1930, two plants each of six varieties were set out in a cooperative experiment at the Kilauea Volcano House garden, where the elevation is 4,000 feet, and two plants each of four varieties were set out in a private garden near Glenwood, island of Hawaii, where the elevation is about 3,200 feet. These locations have a cool, even temperature with a normal annual rainfall of about 100 inches at the Kilauea Volcano House and 189 inches at Glenwood. The plants showed little growth four months after they were set. The horticulturist observed, when on a visit to a private garden on West Maui, where the elevation is 2,300 feet, that both dewberries and blackberries were doing well, and that the former were rather prolific. The blackberry plant fruits well in the vicinity of Kilauea Volcano House on Hawaii and in Makua Valley on Oahu. Introduced raspberry and blackberry plants are reported as growing successfully in the Hamakua district, Hawaii.

KONA SUBSTATION EXPERIMENTS

The station enlarged several of its horticultural projects considerably by making permanent plantings at the Kona substation near Kealakekua, Hawaii, which was recently acquired for experimental

purposes. Approximately 2 acres of land there are now devoted to horticultural plantings. For several years this land had been overgrown with wild grasses and utilized for pasturage. In October and again in November, 1930, the land was deeply plowed and cleared of roots and stones. Planting was begun on December 5, following the early rains. Investigations are concerned principally with the Macadamia-nut tree, coffee, and miscellaneous fruits.

FRUIT AND NUT PLANTS UNDER OBSERVATION

An annotated list of the plants under observation is given herewith:

Macadamia-nut tree (*Macadamia ternifolia*): 10 trees (No. 5589)[3], 19 trees (No. 5588), 1 tree (No. 5481) producing large nuts, and 2 trees (No. 5482) producing thin-shelled nuts.

Pili nut (*Canarium ovatum*): 1 tree (No. 5601).

Citrus: Pomelo or grapefruit (*Citrus grandis*)—Royal variety, 1 tree (No. 1685), Whitney Imperial variety, 1 tree (No. 2704), and Marsh variety, 1 tree (No. 1585), Victoria variety, 2 trees (Nos. 4835.1 and 4835.2), and a Siamese variety, 1 tree (No. 5501); lemon (*C. limonia*)—rough variety, 1 tree (No. 1596), Ponderosa variety, 1 tree (No. 2938), Eureka variety, 1 tree (No. 1653.1); lime (*C. aurantifolia*)—Kusaie variety, 1 tree (No. 5592), a Tahitian hybrid, 2 trees (Nos. 4650.1 and 4650.2), Rangpur variety, 1 tree (No. 5577); orange (*C. sinensis*)—a Hawaiian variety, 6 trees (Nos. 5570.1, 5570.2, 5570.3, 5570.4, 5570.5, and 5570.6), Ruby variety, 1 tree (No. 1561.1), Thomson, 2 trees (Nos. 1609.1 and 1609.2), and Valencia variety, 1 tree (No. 1590.1).

Coffee: a Hawaiian variety (*Coffea arabica*), 15 plants (No. 5497); Robusta variety (*C. robusta*), 18 plants (No. 5575); and 9 trees of unknown varieties.

Papaya (*Carica papaya*): Solo variety, 200 plants (No. 5595).

Mulberry (*Morus nigra*): 4 plants (No. 5593).

Avocado (*Persea americana*): 1 tree each of the varieties Nabal (No. 4467.1), Rey (No. 5532.2), Panchoy (No. 4253), Beardslee (No. 4075.2), Ilialu (No. 4696), Haley (No. 4821.2), Ishim (No. 4261), Kaguah (No. 4433), Linda (No. 5547), Sexton (No. 3841), Dry (No. 5514), and Lewis (No. 4848), and two trees of the variety Fuerte (Nos. 4559.1 and 4559.2).

Sapucaia nut (*Lecythis zabucajo*): 2 trees (No. 5484).

Cashew nut (*Anacardium occidentale*): 2 trees (No. 5522).

Egg fruit (*Lucuma nervosa*): 1 tree (No. 5535).

Sugar-apple (*Annona squamosa*): 1 tree (No. 5490).

Kawa (*Nephelium pinnatum*): 1 tree (No. 5400).

Surinam cherry (*Eugenia uniflora*): 1 tree (No. 5563).

Star-apple (*Chrysophyllum cainito*): 1 tree (No. 5594).

Passiflora spp.: 6 trees (*P. alata*) (No. 5513); Lilikoi variety (*P. edulis*), 4 trees (No. 5510); 1 hybrid tree (No. 5511); and a Fiji variety, 1 tree (No. 5478).

Litchi (*Litchi chinensis*): San Hing variety, 1 tree (No. 3890); and Hak-Ip variety, 1 tree (No. 3878).

Mabolo (*Diospyros discolor*): 2 trees (No. 5569).

Fig (*Ficus carica*): Kadota variety, 1 tree (No. 5567); and Mission variety, 1 tree (No. 5566).

Lanzon (*Lansium domesticum*): 2 trees (No. 5390).

Garcinia (*Garcinia binucao*): 1 tree (No. 5498).

Mamey apple (*Mammea americana*): 2 trees (No. 5568).

Cacao (*Theobroma cacao*): 2 trees (No. 5565).

Ceriman (*Monstera deliciosa*): 1 tree (No. 5564).

Bulso (*Gnetum indicum*): 1 tree (No. 5448).

Vangueria edulis: 1 tree (No. 5397).

Tung-oil tree (*Aleurites fordii*): 1 tree (No. 5560).

Brazil cherry (*Eugenia dombryi*): 2 trees (No. 5561).

Breadfruit (*Artocarpus incisa*): unknown variety, 1 tree (No. 5474); and 1 tree from Tahiti each of the varieties Kuahe (No. 5473), Hamoa (No. 5406), Puera (No. 5424), and Ula Maopo (No. 5491), Morave (No. 5401) from Rarotonga, and a seedy kind (No. 5391) from the Philippines.

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[3] Number under which the plants were received at the station.

Tomato (*Lycopersicon esculentum*) : 50 plants each of the varieties Landreth (No. 5553) and Globe (No. 5549) ; 40 plants each of the varieties Earliana (No. 5555), Great Baltimore (No. 5550), Break O'Day (No. 5554), Norton (No. 5552), Marglobe (No. 5551), Walter Richard (No. 5548), Bonny Best (No. 5557), and Bloomsdale (No. 5556) ; and 35 plants of a hybrid (No. 5590).

INTRODUCTIONS

About 70 kinds of fruit plants were introduced at Kona during the year and included the following:

Cashew nut (*Anacardium occidentale*) (Nos. 5519, 5522, and 5562)[4]; attalea palm (*Attalea gomphococca*) (No. 5520) ; papaya (*Carica papaya*) (Nos. 5521, 5545, 5595, and 5597) ; white sapote (*Casimiroa edulis*) (No. 5523) ; sapote (*Calocarpum mammosum*) (No. 5546) ; palm (*Guilielma utilis*) ; poha (*Physalis peruviana*), Cape Gooseberry variety (Nos. 5525 and 5526) ; Jambolan plum (*Syzygium cumini*) (No. 5527) ; avocado (*Persea americana*), Bicknell variety (No. 5528), Makai variety (No. 5531), Rey variety (No. 5532), Mauka variety (No. 5533) ; Linda variety (No. 5547), and Mexican variety (No. 5599) ; *Saraca indica* (No. 5529) ; jackfruit (*Artocarpus integra*) (Nos. 5530 and 5603) ; magnolia (*Magnolia grandiflora*) (No. 5534) ; egg fruit (*Lucuma obovata*) (No. 5535) ; breadfruit (*Artocarpus incisa*), Aveloloa variety (No. 5536), Ulumanua variety (No. 5537), Puou variety (No. 5538), Maopo variety (No. 5539), miscellaneous kinds (No. 5540), Ulumasee variety (No. 5541), and Ulu-Puou variety (No. 5542) ; carob tree (*Ceratonia siliqua*) (No. 5543) ; red castor bean (*Ricinus* sp.) (No. 5544), tomato (*Lycopersicon esculentum*), Walter Richard variety (No. 5548), Globe variety (No. 5549), Great Baltimore (No. 5550), Marglobe variety (No. 5551), Norton variety (No. 5552), Landreth variety (No. 5553), Break O'Day (No. 5554), Earliana variety (No. 5555), Bloomsdale variety (No. 5556), Bonny Best variety (No. 5557), and a hybrid (No. 5590) ; Ceylon olive (*Elaeocarpus serratus*) (No. 5558) ; *Inga edulis* (No. 5559) ; tung-oil tree (*Aleurites fordii*) (No. 5560) ; Brazil cherry (*Eugenia dombeyi*) (No. 5561) ; Surinam cherry (*E. uniflora*) (No. 5563) ; ceriman (*Monstera deliciosa*) (No. 5564) ; cacao tree (*Theobroma cacao*) (No. 5565) ; fig (*Ficus carica*), varieties Mission (No. 5566) and Kadota (No. 5567) ; mamey apple (*Mammea americana*) (No. 5568) ; mabolo (*Diospyros discolor*) (No. 5569) ; Hawaiian variety of orange (*Citrus sinensis*) (No. 5570) ; horseradish-tree (*Moringa oleifera*) (No. 5571) ; yellow strawberry guava (*Psidium lucidum*) (No. 5573) ; wild Javan raspberry (*Rubus* sp.) (No. 5574) ; coffee (*Coffea arabica*) (No. 5575) ; amaryllis (*Amaryllis* sp.) (No. 5577) ; *Parkia speciosa* (No. 5578) ; sapucaia nut (*Lecythis zabucajo*) (No. 5579) ; Macadamia-nut tree (*Macadamia ternifolia*) (Nos. 5588 and 5589) ; sugar-apple (*Annona squamosa*) (No. 5591) ; Kusaie lime (*Citrus limonia*) (No. 5592) ; black mulberry (*Morus nigra*) (No. 5593) ; star-apple (*Chrysophyllum cainito*) (No. 5594) ; *Passiflora fruticosa* (No. 5596) ; *Attalea cohune* (No. 5598) ; mahogany (*Swietenia mahagoni*) (No. 5600) ; pili nut tree (*Canarium ovatum*) (No. 5601) ; and allspice (*Pimenta officinalis*) (No. 5602).

ARBORETUM

Since the organization of the station in 1901 the horticultural division has developed several small experimental orchards of such leading fruits as the avocado, citrus, mango, banana, litchi, papaya, and fig, and also a group of miscellaneous fruit trees. All have been found to be of value for investigational purposes and as a source of propagating material for distribution to cooperative and private growers both in the Territory of Hawaii and in other tropical and subtropical parts of the world. These orchards are also of great assistance to entomologists of the United States Department of Agriculture who are now in Hawaii studying the Mediterranean fruit fly (*Ceratitis capitata*) and possibly such other undesirable

[4] Number under which the plants were received at the station.

insects as the Japanese beetle (*Adoretus sinicus*) and the mango weevil (*Cryptorhynchus mangiferae*).

The station is suitably located for a great many of the species of crop plants tried. In soil and climatic conditions it is typical of the greater portion of the agricultural land both in the Territory and in other tropical and subtropical countries. These facts were appreciated by the Hawaiian Government (*7 p. 95*) as early as the year 1893, when the station land was set apart for use as a botanical garden or arboretum, and block plantings were begun in acre plats and half-acre plats. These areas now form a forest of silver wattle and black wattle (forms of *Acacia decurrens*), silk-oak (*Grevillea robusta*), *Eucalyptus robusta*, ironwood or beefwood (*Casuarina quadrivalvis*), and camphor (*Camphora officinalis*), and there are a few smaller areas of miscellaneous species, such as the Ceara rubber (*Manihot glaziovii*), Macadamia-nut tree (*Macadamia ternifolia*), Hevea rubber (*Hevea braziliensis*), banana (*Musa* spp.), allspice (*Pimenta vulgaris*), tung-oil nut tree (*Aleurites fordii*), mountain apple (*Eugenia malaccensis*), and sisal (*Agave sisalana*). These plantings have clearly demonstrated the wisdom of the original plan.

The present plan to put out block or large-plat plantings of economically promising tropical fruit and nut trees is a logical development of the work begun here over 30 years ago. This economic tropical arboretum, located just within the Torrid Zone in very healthful surroundings, is in touch with a number of scientific laboratories, libraries, and scientific workers, and presents great advantages for agricultural research. It has been so recognized by a number of branches of the United States Department of Agriculture. The recently approved increased development of the arboretum has started what is hoped will eventually become an extensive area devoted to many species of crop plants for thorough scientific study. Experimental station lands heretofore not fully utilized for crop experiments are being cleared, deeply plowed, and divided into block areas varying from ¼-acre to ½-acre plats of such plants as annonas (*Annona* spp.), breadfruit (*Artocarpus incisa*), pili or canary nut (*Canarium ovatum*), carob (*Ceratonia siliqua*), coffee, cork oak (*Quercus suber*), durian (*Durio zebethinus*), *Eugenia* spp., guava (*Psidium* spp.), Japanese chestnut (*Castanea crenata*), kou (*Cordia subcordata*), lanzon (*Lansium domesticum*), *Lucuma* spp., longan (*Euphoria longana*), Macadamia nut (*Macadamia ternifolia*), mahogany (*Swietenia mahagoni*), mamey apple (*Mammea americana*), sapote (*Calocarpum mammosum*), mangosteen (*Garcinia mangostana*), mulberry (*Morus* spp.), Panama berry (*Muntingia calabura*), *Passiflora* spp., pejibaye palm (*Guilielma utilis*), persimmon (*Diospyros* spp.), pomegranate (*Punica granatum*), rednut (*Hicksbeachia pinnatifolia*), sapucaia (*Lecythis zabucajo*), sapodilla (*Achras zapote*), Tahitian chestnut (*Inocarpus edulis*), tamarind (*Tamarindus indicus*), teak (*Tectona grandis*), tropical olive (*Elaeocarpus serratus*), wampi (*Clausena wampi*), white-sapote (*Casimiroa edulis*), vi-apple (*Spondias cytherea*), and tung-oil tree (*Aleurites fordii*).

REPORT OF THE NUTRITION LABORATORY OF THE HOME ECONOMICS DIVISION

By Carey D. Miller

VITAMIN CONTENT OF CHINESE CABBAGE

Experiments with white rats showed raw Chinese cabbage (*Brassica chinensis*), like other green vegetables, to be a very good source of vitamin A. When Sherman's standards were used, feeding 0.5 gram of the cabbage once a week, equivalent to a daily (except Sunday) supplement of 0.083 gram, was found to give three times the expected gain of 25 grams of body weight for the eight weeks covered by the test. All the larger amounts yielded much greater gains. Experiments on rats fed bran-salted Chinese cabbage indicated a considerable loss of vitamin A in the cabbage resulting from the salting process.

The rice bran used in salting the cabbage was tested on rats to determine its vitamin B content and was found to have high antineuritic properties. Feeding 0.1 gram daily, except Sunday, gave about 30 grams of gain in body weight in the eight weeks covered by the test. Rats were used to test the vitamin B content of raw and salted Chinese cabbage. About 4.5 grams of the raw cabbage seems to be the unit quantity required to supply vitamin B.

The vitamin G content of the bran was tested on rats and found to be low as compared with the vitamin B content. Thus far 23 rats have been used to determine the vitamin G content of the raw and the salted cabbage. At least 5 grams of the raw cabbage, and probably 10 grams of the salted cabbage, are required daily to effect recovery from symptoms of dermatitis.

Experiments on guinea pigs indicated that 2 to 3 grams of the fresh cabbage should be fed daily to protect the animals from scurvy. The bran-salted and the plain-salted cabbage seem to contain only about one-tenth as much vitamin C as does the fresh cabbage.

VITAMIN CONTENT OF THE HAWAII SHELLFISH OPIHI

In continuation of studies of the foods used by both ancient and modern Hawaiians, experiments were begun on the food value of their favorite shellfish, the opihi (*Helcioniscus exerata; H. argentatus*). No figures were available on the organic nutrients of opihi. Analyses showed opihi to contain 76.45 per cent of water, 17.6 per cent of protein (N × 6.25), 1.72 per cent of fat (ether extract), and 2.79 per cent of ash. The ether extract had an odor distinctly like that of cod-liver oil.

Preliminary experiments with rats showed opihi to be a very good source of vitain A. Feeding 0.5 gram of the fresh opihi daily caused the animals to gain 190 grams in eight weeks. Later experiments showed that rats, when fed 0.1 gram of opihi once a week (equivalent to about 0.016 gram daily, except Sunday), lost in weight and died before the close of the experiment. Rats fed 0.2 gram per week gained 60 to 70 grams in eight weeks, whereas those fed 0.4 to 0.5 gram per week gained about as much as those receiving 0.1 gram of cod-liver oil per week. Considered on a moisture-free basis, and measured by the rat-growth method, opihi is as good a source of

vitamin A as is cod-liver oil, because 0.4 gram of the raw fresh opihi is equivalent approximately to 0.095 gram of moisture-free material.

Preliminary experiments with rats showed opihi to be very low in vitamin B content. All rats receiving 1, 2, and 3 grams daily lost weight markedly and most of them died before the close of the experiment. One rat receiving 4 grams of opihi gained 42 grams in weight in eight weeks. A second lot, when fed daily 3.5 or 4 grams of opihi, lost 17 to 29 grams in weight per animal. The control animal in this lot lived longer than usual. A third lot, when fed 4 grams of opihi daily, like the animal in the first lot, gained 23 to 30 grams in weight in eight weeks. Possibly there is a seasonal variation in the vitamin B content of opihi, as is the case with the vitamin A content of oysters in New Zealand, or possibly the rats in the second lot were unusual.

In experiments with rats to determine the vitamin G content of opihi, 2 grams of fresh opihi fed daily (except Sunday) caused an average gain of about 75 grams in body weight in eight weeks, but did not always effect a complete recovery from symptoms of dermatitis. Histological work done by a member of the zoology division of the University of Hawaii indicated that even when a gross examination shows apparent recovery from any symptoms of dermatitis the epithelium may be far from normal.

Experiments with guinea pigs showed opihi to have no antiscorbutic properties, even when 4 grams, the largest quantity the animals could be induced to eat, were fed daily. In fact, after 21 days the animals seemed to be in worse condition than were the usual controls. Histological examination of the incisor teeth of the opihi-fed group, as recommended by Höjer (*6*) and later by Eddy (*3*) showed complete degeneration of the odontoblasts.

The line test was used to determine the vitamin D content of opihi (Stenbock's diet 2965). Feeding 4 or 5 grams of fresh opihi daily for eight days gave as complete protection from rickets as did 1 per cent of cod-liver oil in the diet. Feeding 2 grams of opihi daily was not found to be sufficient for complete protection.

HEMOGLOBIN REGENERATION

Nutritional anemia was produced in albino rats by feeding them special milk from the university farm, which contained no copper. The technic used was essentially that of the Wisconsin investigators. Anemic rats fed 4 grams of fresh calf liver daily showed rapid hemoglobin regeneration. Rats fed opihi showed only slight hemoglobin regeneration or none. It is therefore concluded that opihi has little or no value for hemoglobin regeneration in nutritional anemia of the rat. The spleens were found to be much enlarged in all the anemic animals.

VITAMIN C CONTENT OF HAWAII-GROWN ORANGES

Notwithstanding some difficulty in securing a continuous supply of locally grown oranges over a 4-month period because of an unusual season, guinea pigs were fed 1.5 cubic centimeters of locally produced orange juice daily for a period of 90 days. All the animals made

moderate to excellent growth, gaining 110 to 250 grams during the period and showing complete protection from scurvy, when Sherman's method was used. At the end of the 90-day period histological examination of the incisor teeth of the animals showed the juice fed to be 0.7 to 0.5 of the fully protective dose. This finding was to be expected in view of the fact that other investigators have shown that 3 cubic centimeters of orange juice daily are required to protect the teeth.

VITAMIN B CONTENT OF RICE-BRAN BREAD

Since rice bran is generally considered to be a good source of the antineuritic vitamin and was found in experiments by the station to be also an inexpensive source of the vitamin, finding some method of encouraging the use of rice bran in human food was deemed to be worth while. The diet of many children, and of many adults also, in Hawaii is undoubtedly low in this vitamin. The largest baking concern in Honolulu was approached on the subject and willingly offered to bake, for experimental purposes, bread in which 20 per cent of rice bran would be substituted for white flour. The bread was fed to rats. White bread plus rice bran and rice-bran bread and white bread were fed daily in equivalent amounts. The white bread proved to be no better than the basal diet alone. The completed experiments indicated a destruction of about 30 per cent of vitamin B in the rice-bran bread.

BIOLOGICAL VALUE OF THE PROTEIN OF THE PIGEON-PEA SEED

Experiments in which rats were used to determine the biological value of the protein of the seeds of the pigeon pea (*Cajanus indicus*), using the Mitchell paired-feeding method with and without cystine, did not give clear-cut results. Enough pure protein from the seed of the pigeon pea has been prepared for further feeding experiments and for chemical analyses.

REPORT OF THE POULTRY HUSBANDRY DIVISION

By C. M. Bice

SOREHEAD (FOWL POX) CONTROL IN BABY CHICKS

The objects of this experiment are (1) to determine the method of transmission of sorehead (fowl pox), identified as epithelioma contagiosum, to baby chicks; (2) to note the efficiency of a "live virus" vaccine in developing immunity against the disease; and (3) to learn the age at which chicks may be vaccinated successfully. In the report for last year (*2, p. 36*) a method of preventing fowl pox by eliminating the mosquito was described. Nine groups of chicks, 200 to a group, varying in age from 1 day to 16 weeks, are being tested to learn the efficiency of a "live virus" vaccine. One group was vaccinated when 1 day old, and each succeeding group at intervals of two weeks. The "stick" method is being used—the right wing is pierced once in the web portion. The preliminary trial was completed, and a second trial was undertaken. Baby poults were vaccinated against turkey pox. The age for vaccination ranges from 1 day to 2 months.

SEX DETERMINATION IN DAY-OLD PUREBRED CHICKS

In an experiment having for its object the finding of some definite sex-linked character in day-old purebred chicks, voice, length of tail, internal copulatory organs in the vent, and position of chick when held by the nape of the neck or by the feet, were studied. The results were not entirely satisfactory.

BATTERY BROODING METHOD FOR CHICKS

An experiment was begun to compare the relative merits of a fireless battery brooder and an electrically heated battery brooder, and the value of the battery brooder with that of an ordinary canopy-type electric brooder now in use in the poultry division of the station. One test was completed in which 1,000 chicks were grouped as equally as possible in the three types of brooders. Cannibalism was observed in the fireless battery brooder on the nineteenth day of the test, whereas it did not begin in the electrically heated battery brooder until the fifth week. Severe cannibalism took place in both battery brooder groups when the chicks were moved to the colony houses. No cannibalism was observed in the chicks under the electrically heated canopy brooder. Mortality was less than 5 per cent for each group.

PAPAYAS, AVOCADOS, BANANAS, AND SWEETPOTATOES FOR POULTRY

Fattening and laying rations containing varying quantities of fruits and vegetables were fed to poultry to determine the feeding value of the papaya, the avocado, the banana, and the sweetpotato. Twelve lots of 10 birds each were placed on the laying rations beginning October 1, 1930. The information gathered is not complete, and therefore definite conclusions can not be drawn.

RAW CANE SUGAR FOR BABY CHICKS

An experiment was begun to determine the feeding value of raw cane sugar for baby chicks. One group of 90 chicks was fed a ration containing 5 per cent of raw cane sugar; a second group of 90 was fed a ration containing 10 per cent sugar; and a third group of 90 was used as a check, receiving no sugar supplement in their ration. The feeding period lasted 13 weeks. The information gathered on the first trial was not significant for accurate deductions and conclusions.

MISCELLANEOUS NOTES

The most common breeds of poultry in Hawaii are maintained at the university farm for instructional and experimental purposes. The minor experiments under way entirely with Territorial funds include (1) determination of the effect of various incubation temperatures under Hawaii climatic conditions, (2) determination of the value of electric lights as a possible preventive of fall molt in early hatched pullets, (3) determination of the part the sire plays in increasing egg production, and (4) determination of the possibility of rearing turkeys in confinement.

REPORT OF THE SOIL PHYSICS DIVISION

By H. A. Wadsworth

The work of the year was concentrated on two investigations. One of these dealt with factors affecting the rate and height of capillary rise of water through soils. Results indicate that capillary rise through soils, or idealized soils, is a compound process in which at least two distinct types of moisture distribution are involved. In the simplest case the initial phase of such rise is characterized by an exponential form for the rise-time curve. The resulting moisture content is uniform, except for trapped air, and essentially equal to the saturation percentage. The second phase of the rise is marked by the parabolic rise-time curve already noted by other investigators. The moisture content decreases uniformly and continuously from the saturated zone at its lower end to about the field capacity at its upper end.

In the second investigation a preliminary study was made of the correlation of the ratios of the moisture equivalents and wilting coefficients of a selected list of economic soils and the silica sesquioxide ratios of the extracted colloids of the soils.

REPORT OF THE HALEAKALA SUBSTATION

By H. F. Willey

GENERAL STATEMENT

At the Haleakala substation selective-breeding work with the pigeon pea was continued; green-manuring cultural tests on pineapples, with and without fertilizers, were under way; and variety tests with green-manuring crops and with fruits and vegetables were made. The varieties of pigeon pea New Era Strain D, Indian, and Dwarf New Era, and a hybrid were retained to serve as a source of future seed supply. Over 600 different lots of pigeon peas were under test. Seventeen varieties of cultivated grasses were grown. The coarser, higher-growing grasses are useful as windbreaks and have value as feed for livestock. In a grazing experiment Rhodes grass (*Chloris gayana*) was found to be the least palatable of the grasses fed to cows but was as readily eaten by horses and mules as are paspalum or Dallis grass (*Paspalum dilatatum*), Bahia grass (*P. notatum*), orchard grass (*Dactylis glomerata*), and Harding grass (*Phalaris tuberosa*). The root crops tested included cassava (2 varieties), edible canna (3 varieties), Hawaii and Japanese dryland taro (20 varieties), arrowroot (*Maranta arundinacea*) (1 variety), and sweetpotatoes (11 varieties). The vegetables under test included lettuce (3 varieties), beans (6 varieties), and garbanzo peas (*Cicer* sp.) (1 variety). The nontree fruits tested included grapes (16 varieties), pohas (*Physalis peruviana*) (2 varieties), and strawberries, tomatoes, blackberries, raspberries, currants, dewberries, loganberries, gooseberries, and pineapples (1 variety each).

A plat of pineapples, 85 by 165 feet, yielded 12,837 pounds of fruit, or at the rate of approximately 18 tons per acre on an elevation (2,160 feet) that 10 years earlier was not considered suitable for successful pineapple growing. Some pineapples were matured about 3

miles from the substation along the mountain side where the elevation is approximately 3,300 feet. The most promising green-manuring crops for pineapples appear to be the blue lupine (*Lupinus azureus*), the jack bean (*Canavali ensiformis*), and the hairy vetch (*Vicia villosa*). The fruit, nut, and coffee trees under test included avocado, strawberry guava, Natal plum or carissa (*Carissa grandiflora*), pomegranate, mango, mulberry, prune, nectarine, lime, orange, jujube, Bartlett pear, Newtown pippin apple, cherimoya, loquat, fig, longan, pecan, almond, Macadamia nut, English walnut, Japanese persimmon, rose apple or malabar-plum (*Caryophyllus jambos*), Brazil cherry, annonas, Red Mexican banana, Chinese banana, and coffee.

The eucalyptus trees planted in 1922 have not only served their original purpose as effective windbreaks but have also furnished sufficient posts for use in repairing fences at the substation. One hundred and fifty eucalyptus posts were used to fence the experimental plats at the higher elevations. Several species of evergreen trees, including the arbor vitae planted in 1928, made some growth during the year.

DISTRIBUTION OF SEEDS AND PLANTS

The general distribution of seeds and plants during the year included 1 packet of seeds and 15 plants of *Meibomia rensoni*, 50 pounds of pigeon-pea seed, 12 pounds of jack-bean seed, 15 pounds of lupine-bean seed, 15 mulberry cuttings, 1 pound of pop-corn seed, 500 edible canna tubers, 1,025 sweetpotato cuttings, 700 strawberry plants, 5,000 Napier and Merker grass cuttings (plus eight 1½-ton truck loads), 100 Uba cane cuttings, 10 banana plants, 26 pounds of field-corn seed, 4 plants and one-fourth of a pound of carissa seed, one-fourth of a pound of strawberry guava seed, 25 avocado seedlings, 2 persimmon seedlings, 2 pounds of *Dolichos lablab* seed, 16 cuttings of cassava, 15 cuttings of figs, 125 cuttings of hibiscus, 5 dewberry plants, 5 downy myrtle plants, 5 thornless blackberry plants, and 10 cuttings of roses.

EXPERIMENTS AT THE HIGHER ELEVATIONS

Four experimental plats at elevations of approximately 3,500, 4,800, 5,500, and 6,400 feet, respectively, were established during the year for the development of strains of pigeon peas and pasture grasses that will succeed in these elevations. Approximately 20,000 acres of pasture land on the slopes of Haleakala alone are maintaining 2,000 steers or cows, at the rate of one animal to 10 acres. There are extensive areas of similar grazing lands on certain other islands of the group. If the forage on these areas can be improved the herd carried there can be greatly increased.

OLINDA

A 4-acre plat was established at Olinda, at an elevation of approximately 3,500 feet. This area is badly infested with gorse and with whin. On March 17, 1931, 61 lots of pigeon-pea seeds were sown. Some of these seeds were obtained from the university farm,

some from Pensacola Street station, and some from the Haleakala substation. A number of the lots did not germinate well, but others produced plants that were 8 to 10 inches tall on June 15, 1931. On May 26, 82 lots of pigeon-pea seeds were sown. Some of these came from the same sources as the previously mentioned lots, and some came from the central station in Honolulu and from the United States Department of Agriculture, Washington, D. C. On March 17, 1931, plantings were made of the lupine bean, hairy vetch, garbanzo pea, jack bean, the Scarlet Runner bean, and the Black Mauritius velvetbean. Of these plantings, the lupine bean is making the best showing. On March 17 plantings were also made of Merker grass (a form of *Pennisetum purpureum*), Napier grass, *Paspalum notatum*, and *P. dilatatum*.

UKELELE

At Ukelele, where the elevation is approximately 4,800 feet, a ½-acre plat in the grazing area was fenced for experimental purposes. Fence posts, wire, feed, tools, and other supplies were transported by auto truck to the end of the road at Idlewild and then sent by pack horse or small sled to Ukelele. This plat was in heavy grass sod and required a great deal of work to put it in condition for planting. On May 21, 1931, 87 lots of pigeon-pea seed were planted. These seeds came from the university farm, the Pensacola Street station, the Haleakala substation, and the United States Department of Agriculture. The percentage of germination was about the same as that in the first plantings at Olinda. Pieces of the turf or bunches of Napier grass, orchard grass, molasses grass, kikuyu grass, jaragua grass, *Lolium westerwoldicum*, Rhodes grass, *Paspalum notatum*, *P. dilatatum*, and redtop grass were planted May 21 and started to grow promptly. The average temperature at Ukelele is from 10° to 12° lower than it is at the Haleakala substation.

MOUNTAIN PADDOCK

At Mountain Paddock, where the elevation is approximately 5,500 feet, a ½-acre plat was fenced and on May 20, 1931, 114 lots of pigeon-pea seed were sown. Eighty-seven were duplicates of those planted at Ukelele and at Olinda, and the others came from the Haleakala substation. Grasses of the same species as those planted at Ukelele were sown on May 20. Some hairy vetch was also planted. The percentage of germination was about the same as at Ukelele. The fencing material for the plat was hauled by sled from Idlewild, about 2½ miles distant. Tools and seeds were carried from Ukelele, about 2 miles distant.

PUU NIANIAU

A ½-acre plat of land was fenced at Puu Nianiau, where the elevation is approximately 6,400 feet. This elevation is about as great as is needed for experiment on the island of Maui, because most of the higher lands are included in the National Park boundaries and are not available for grazing. The fencing material for the plat

was hauled from Idlewild, about 3½ miles distant. Tools and seed were carried from Ukelele, about 2¼ miles distant. On May 18, 1931, plantings were made of 87 lots of pigeon peas and grasses similar to those tested at the other altitudes. Black Mauritius velvet beans, hairy vetch, lupine beans, Scarlet Runner beans, and garbanzo peas were also planted. The percentage of germination was essentially the same as that at the other places. The experiments at Ukelele, Mountain Paddock, and Puu Nianiau are on land belonging to the Haleakala Ranch Co., whose manager, S. A. Baldwin, is cooperating with the station in making the areas available for experiment. He has also made available the buildings of an old camp at Ukelele for use of substation employees who work at the higher elevations.

REPORT OF THE KONA SUBSTATION

By R. K. Pahau

The 3.28-acre tract on which the Kona substation is located was made available to the station by Executive Order No. 407, dated April 8, 1930. The superintendent's residence and the outbuildings

Figure 14.—General view of the Kona substation from the northwest corner of the grounds, April 4, 1931

were erected during the summer of 1930, and land clearing preparatory to planting was begun October 22, 1930. Tree planting began December 5, 1930. A number of outlying experiments with coffee, Macadamia-nut trees, akala-berry plants, and miscellaneous fruits were begun largely in cooperation with private coffee planters and ranch owners. While the superintendent keeps in touch as closely as possible with these outlying experiments, each project leader largely directs and oversees the work by making trips from the central station in Honolulu whenever it is necessary. The tropical fruit and nut tree plantings of the horticultural division of the station occupy most of the available land in the 3-acre tract originally set aside for the substation, and efforts are being made to obtain additional adjoining land.

During the year 729 feet of road was constructed. The newly constructed buildings were inventoried at $4,805, and the stock, land, and equipment at $1,927.55. A set of United States Weather Bu-

FIGURE 15.—Meteorological instruments, Kona substation, April 4, 1931

reau instruments was installed January 1, 1931. During the six months beginning January 1, 1931, the total rainfall was 24.83 inches. During the three months beginning April 1, 1931, the mean maximum temperature was 75.9° F., the mean minimum temperature was 61.9°, and the mean temperature was 68.9°. The maximum

FIGURE 16.—Laying out the experimental orchard at the Kona substation, April 3, 1931

temperature for the same period was 82°, and the minimum temperature was 55°.

Plantings made during the year included 32 Macadamia-nut trees of various strains, 23 citrus trees (orange, shaddock, pomelo, and

lime), 42 coffee seedling trees (including 15 Hawaiian coffee (*Coffea arabica*) seedlings from Molokai, and 18 seedlings of *C. robusta*), about 200 trees of the Solo variety of papaya and 14 avocado varieties, about 48 poha plants, 56 miscellaneous fruit trees, 1 to 3 each of 33 species and varieties (including breadfruit, fig, and cacao), and 11 varieties of tomato. Various kinds of vegetables were grown as intercrops among the fruit trees.

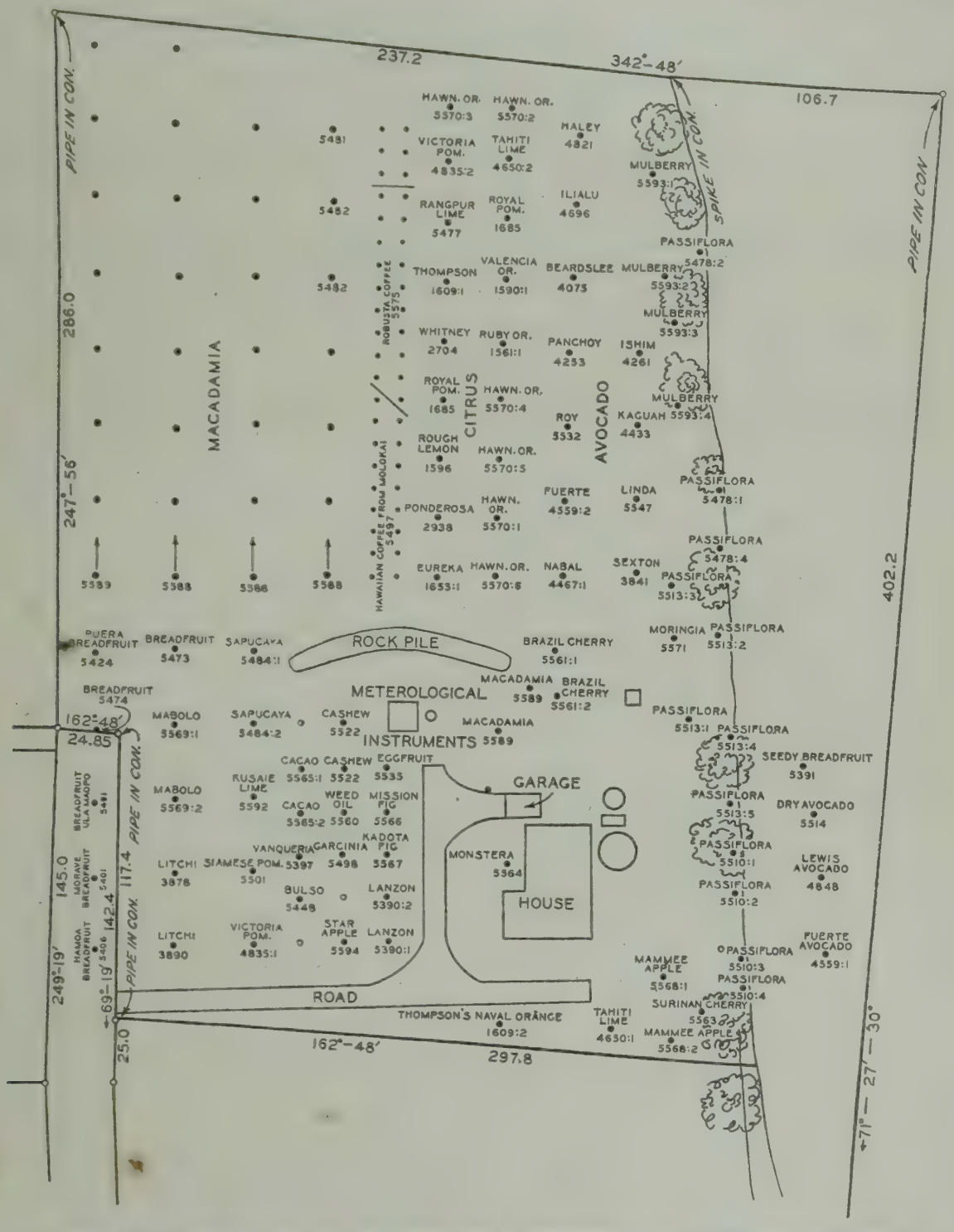

FIGURE 17.—Plan of horticultural plantings, Kona substation, Kealakekua, Hawaii

The livestock of the substation consisted of a flock of 19 Rhode Island Red hens and 2 cockerels, a registered Holstein bull, a cow, a calf, a registered Tamworth sow, and a registered Berkshire boar that is available to the community for breeding.

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HAWAII AGRICULTURAL EXPERIMENT STATION

HONOLULU, HAWAII

Under the joint supervision of the
UNITED STATES DEPARTMENT OF AGRICULTURE AND THE
UNIVERSITY OF HAWAII

Washington, D. C. May, 1933

REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION, 1932

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SUMMARY OF INVESTIGATIONS

By J. M. WESTGATE, *Director*

The low prices of sugar and pineapples, the leading agricultural products of Hawaii, have stimulated interest in other crops, and in the rather extensive areas of marginal and submarginal lands in the islands whose profitable utilization presents serious problems.

Progress has been made in developing various outlying experimental tracts acquired in 1931. Continuing its cooperative work with the Territorial department of forestry, the station extended its planting to some of the higher elevations on the island of Hawaii where there

are extensive areas that would be benefited by the development of improved crops or by the adoption of agricultural practices especially adapted to these areas.

Experiments were continued during the year on three of the larger islands with pigeon peas; with green-manure, forage, and vegetable crops; and with range grasses. Some 400 new selections of pigeon peas were under test, and progress was made in developing a suitably flavored strain for human consumption. This strain is of especial interest to the many persons on the islands who, to an increasing extent, are growing their food supplies. A bulletin on the pigeon pea, issued during the year (*7*),[1] covers the work of 25 years with the pigeon pea at the station and the University of Hawaii. Different spacings of the hills in the row were compared in experiments with 64 different green-manure crops, and 10 varieties were uniformly spaced and cut back at different heights to determine the effect on seed production. A nursery containing 145 different species and varieties of grasses and legumes was established, and comparative yield tests of four of the most popular large forage grasses for dairy cows were under way. Experiments with lettuce, potatoes, sweetpotatoes, garden beans, taro, peanuts, ginger, and red peppers were continued.

The eighth year of experiments to determine how feeding sugarcane molasses affected milk yield and breeding records of dairy cows was completed. Tests of the effect of feeding sprouted oats on the breeding ability of dairy cows and brood sows have so far failed to show conclusive results. Feeding of raw sugar as a supplement to fattening rations for swine was continued.

A series of experiments was begun to determine the value of the Mitscherlich pot test as a means of determining the fertilizer requirements of coffee. Studies of the oil content of the avocado were continued. Investigations were begun to obtain nicotine derivatives effective as stomach poisons for certain classes of insects. When grown locally, some strains of tobacco have been found to contain much higher percentages of nicotine than do others. This has an important bearing on the development of the local production of insecticides for use on pineapple fields.

The horticultural work, which is being done at the central station in Honolulu, at the Tantalus substation where the elevation is 1,000 feet, at the Kona substation, Island of Hawaii, where the elevation is approximately 1,500 feet, and at several other places representing material differences in altitude, and in moisture and soil conditions, was primarily concerned during the year with the establishment of new varieties of coffee, Macadamia nut, avocado, citrus, litchi, akala, and passion fruit. Substantial progress was made in developing an economic tropical arboretum. Budding, grafting, and other methods of vegetative propagation of tropical plants were studied.

Studies of the vitamin content of Chinese cabbage, the biological value of the protein of pigeon-pea seed, and the nutritional value of the shellfish locally known as "opihi" were continued, and vitamin studies of the local mountain apple were begun.

It has been demonstrated by the station that sorehead (fowl pox) is transmitted to baby chicks by the mosquito. Vaccination with "live virus" has been shown to be effective against this disease as

[1] Italic numbers in parentheses refer to Literature Cited, p. 23.

early as the fifth week with chicks, the fourth week with turkey poults, and the first week with squabs. Cane molasses was shown to be an economical constituent of rations for both chicks and older fowls. Studies were continued to discover some sex-linked character, readily observed, which would furnish a basis for sex determination of purebred day-old chicks. Cull and surplus papayas, avocados, bananas, and sweetpotatoes were used to advantage as supplements to both laying and fattening rations. Turkeys were raised successfully in confinement when the young poults were vaccinated against sorehead.

The physical significance of the silica-sesquioxide ratios of soil colloids was further studied. The moisture equivalents were found to depend on the amount and the nature of the colloidal material. There appeared to be a definite, direct relation between the silica-sesquioxide ratio and the moisture equivalent of all the soils tested.

Of the 600 or more lots of pigeon peas previously under trial at the Haleakala substation, 100 of the most promising were selected for further comparative test. Tests of numerous grasses, green-manure and root crops, berries, fruits, nuts, and vegetables were continued. Acclimatization and selective breeding work was carried on at different elevations. At Puu Nianiau, where the elevation is 6,400 feet, most of the plantings failed to do well. At the lower elevations most of them succeeded.

Substantial progress has been made at the Kona substation during the two years since its establishment. The work has centered largely on coffee, Macadamia nut, and akala or Hawaii raspberry, but plantings of about 25 different species of fruit and nut trees and plants are under observation. Some work with swine, poultry, and dairy cattle has been started. The substation employs a full-time superintendent who also looks after the outlying experiments under the supervision of the experiment-station specialist in general charge of each particular line of work.

The income of the station for the fiscal year ended June 30, 1932, was increased by $2,000, the authorized increment of the Adams fund, making the total of the Adams fund allotment $7,000 for the year. This fund is available only for fundamental scientific research. The total income of the station for the year was $43,520.

REPORT OF THE AGRONOMY DIVISION

By C. P. Wilsie and M. Takahashi

PIGEON PEAS

More than 400 selections of pigeon peas (*Cajanus indicus*) were grown during the year. Many of the individual selections, progenies of single plants of the 1931 season, showed great variability. Fewer than half of them produced progenies of uniform color of flower, pod, and seed. Apparently much natural crossing had taken place in the breeding stocks. Experiments were started to determine the percentage of natural crossing between varieties and strains grown in adjacent-row plats. The need of growing pure strains in complete isolation or of covering the flowers to assure self-pollination was indicated.

A selection from the Puerto Rico variety Prensado produced pigeon peas apparently of very desirable quality for table use. (Fig. 1.) A planting of this selection is being carefully rogued for variant types, and if a pure strain is established it is to be tested for quality and for yield as compared with the standard varieties. The object of the breeding work is to develop improved strains of pigeon peas for use as green manure, forage, and food.

FIGURE 1.—The Puerto Rico variety of pigeon pea, Prensado. Desirable for table use

GREEN-MANURE CROPS

A number of green-manure crops were grown to determine the relative amounts of green-top growth produced within six months. *Crotalaria striata* produced at the rate of 18.6 tons (green weight) per acre, and *Cajanus indicus*, 17.6 tons. Species producing much lower yields were *Crotalaria spectabilis*, *C. retusa*, *Canavalia ensiformis*, *Cassia occidentalis*, *C. tora*, and *Tephrosia candida*.

The effect of spacing on seed production was studied with a large number of legumes. Results of two years' experiments indicated that for maximum seed production the plants should be spaced more closely than 6 inches apart, in rows 5 feet apart. The Crotalarias were very promising in seed production, 12 species spaced at the rate of 17,424 plants per acre giving an average yield of 1,433 pounds per acre.

In cooperation with the agricultural extension division, 10 varieties of legumes were grown on each of seven plats in the Kona coffee district in order to study their growth between coffee trees and their relative value as green manure.

FORAGE CROPS AND GRASSES

A grass and legume nursery was established during the summer of 1931. Desirable species already growing at the station were transplanted to the nursery, and new species were added to it from time to time. Twelve species of grasses and 40 species and varieties of legumes were introduced from other parts of the world for trial. At the close of the year (June 30, 1932) 45 species of grasses and 100 varieties and species of legumes were growing in the nursery. Observations were made on adaptability of the plants, and on their habits of growth and yield.

Because of the widespread interest of island dairymen in the large forage grasses, an experiment was begun to determine the comparative yields of Napier (elephant) grass (*Pennisetum purpureum*), Merker grass (a form of *P. purpureum*), guinea grass (*Panicum maximum*), and Sudan grass (*Holcus sorghum sudanensis*)—four of the most common and popular of the local forage grasses.

Preliminary studies of Merker grass indicated a difference in color, size, and habit of growth among several strains. Several selections were under test for comparison of desirable features of growth and yield.

SOYBEANS

Twenty-five varieties of late-maturing soybeans (*Soja max*) were introduced for trial through the courtesy of the Division of Forage Crops and Diseases of the United States Department of Agriculture, the Missouri Agricultural Experiment Station, and the North Carolina Agricultural Experiment Station. Many of the varieties originally came from China and from Japan. It is hoped that one or more will prove to have superior value as forage or as food for human consumption.

OTHER CROPS

Five promising head-lettuce hybrids produced by the station were compared with three commercial varieties. None of the station hybrids showed so high a percentage of solid heads as did the commercial variety Mignonette, locally known as "Manoa," but they gave better results than did the Los Angeles Market (New York) and Hanson varieties. From a segregating F_4 hybrid (accession No. 1801) selections were made for types of good quality which will head well.

One hundred and thirty varieties, hybrids, and seedling varieties of sweetpotatoes grown in small plats yielded at acre rates of 6,000 to 35,000 pounds.

Nine varieties of garden beans, obtained from France in 1928, were grown for comparison with station varieties. Although some were outstanding in vigor and yields, none produced so well as did the three station varieties Kentucky Wonder, a hybrid Kentucky Wonder, and a variety known as accession No. 2291. Kentucky Wonder yielded at the acre rate of 22.7 bushels.

In preliminary tests Guam white corn was promising for table use. It is practically the only variety so far tested that withstands insect and disease attacks at the lower elevations.

Various crops were maintained at the station to serve as sources of planting material and to furnish data on yields.

REPORT OF THE ANIMAL HUSBANDRY DIVISION

By L. A. Henke

DAIRY CATTLE

Experiments were begun in 1924 to determine how rations containing 25 per cent of sugarcane molasses affected the milk yield and reproduction of dairy cows. The experiments involved 87 cows and the results showed a slight decrease in yield of milk and butterfat, and a considerable decrease in reproductive efficiency of the cows on the molasses ration.

Thus far, 25 cows exhibiting irregularity in breeding behavior have been fed sprouted oats and 10 have dropped calves. In two instances the feeding of the oats seemed to be helpful and in six instances the evidence was less definite. Of 24 cows in a control group of cows that exhibited irregularity in breeding behavior but were not fed sprouted oats, 9 have calved. The evidence obtained does not show conclusively that sprouted oats are of value in correcting breeding troubles in dairy cows; it indicates that under Hawaiian conditions, with green feed available the year around, the oats are of little value.

SWINE

In experiments (*6, p. 9*) to learn the value of raw sugar in fattening hogs, 81 hogs have been fed rations usually containing 5 to 10 per cent of raw sugar, replacing an equivalent amount of barley in the control ration which consisted of 88 pounds of barley, 8 pounds of tankage, 2 pounds of linseed meal, 1 pound of steamed bone meal, and 1 pound of salt. Green alfalfa was fed to all the hogs. The use of raw sugar in the ration increased the daily gains somewhat and slightly reduced the feed required and the cost per pound of gain.

Of nine sows showing irregular breeding behavior that were fed sprouted oats, six farrowed. The feeding of sprouted oats seemed to be helpful in one case, but in two others the evidence was less definite. Of the eight sows in the control group that were irregular in breeding behavior but were fed no sprouted oats, three farrowed normally and a pregnant sow died. The evidence does not show conclusively that sprouted oats are helpful in improving the breeding behavior of sows.

REPORT OF THE CHEMICAL DIVISION

By J. C. Ripperton and D. W. Edwards

MACADAMIA NUT

Studies of various methods of grading nuts harvested monthly from 12 representative Macadamia-nut trees were carried through a third crop. Certain of the nut characters in the different trees remained remarkably constant, whereas others showed considerable variation. It was found that for a given tree the proportion of culls, mainly immature nuts, may range from more than 80 per cent to less than

1 per cent. The percentage is usually high during the off season and decreases to the lowest point during the months of greatest yields. Nutritional factors are probably chiefly concerned in these differences among trees since they differ greatly from year to year, and in certain instances a tree has continued to drop its crop chiefly as culls throughout the year only to return to normal during the following year.

Further work continued to show inherent differences in the properties of the smooth-shelled and the rough-shelled varieties of Macadamia nut. One orchard of the rough-shelled variety in the Kona district was outstandingly higher in the oil content of the nuts than was any heretofore found, and had relatively few culls. Even with a high oil content, the rough-shelled nuts are noticeably denser and harder in texture. This has an important bearing on their cracking and roasting qualities. Characters such as these are often the determining factors in the selection of commercial varieties of other nuts.

The specific-gravity method of rapidly determining the oil content of the Macadamia nut was further tested and found to be accurate to about ± 0.5 per cent of oil, with both smooth-shelled and rough-shelled varieties.

Nuts of different specific-gravity groups were roasted to determine the dividing line between first-grade nuts and culls. Heretofore this line has been placed at unity, that is, the specific gravity of water, but nuts of a specific gravity between unity and 1.025 were rated as acceptable in flavor and in texture by most of those who tested them. Nuts having a specific gravity greater than 1.025 were classed as culls.

Since the local Macadamia-nut industry is planning to begin the roasting and exporting of the nuts in the near future, experiments have been started to determine the keeping qualities of nuts processed and stored by different methods and for different lengths of time.

SOIL INVESTIGATIONS

The soil and geological survey of the Kona district, conducted in cooperation with the geologist of the Volcano Observatory, United States Geological Survey, was completed and a bulletin entitled, "Survey of the Physical Features That Affect the Agriculture of the Kona District of Hawaii," was published (*9*). It presents the chief features of the geography, climate, and geology of the district, and includes a colored map that shows the principal lava flows, both the recent and the older ones which have an overlying ash mantle of varying thickness. The map also shows the bounds of the present coffee area. The scheme of classification of the soils of Kona is based on the thickness of the ash mantle and the type of the underlying lava. Microscopic examinations and mechanical analyses of the different soil types were made. The volcanic ash has been completely weathered to a characteristic yellow residue, probably palagonite, whereas little decomposition of the crystallizing lava has yet taken place. This has resulted in relatively high percentages of clay fraction, due to the decomposed ash, and of the coarse fractions down to fine sand, due to the undecomposed lava fragments, but low percentages of the intermediate fine sand and silt fractions. This survey makes evident the large area of pasture or unused land in Kona suitable for coffee and for other crops should future economic conditions justify their development.

COFFEE

REJUVENATION OF OLD PLANTINGS

Study of different methods of rejuvenating old coffee plantings in the Hamakua region was continued. Differences resulting from the

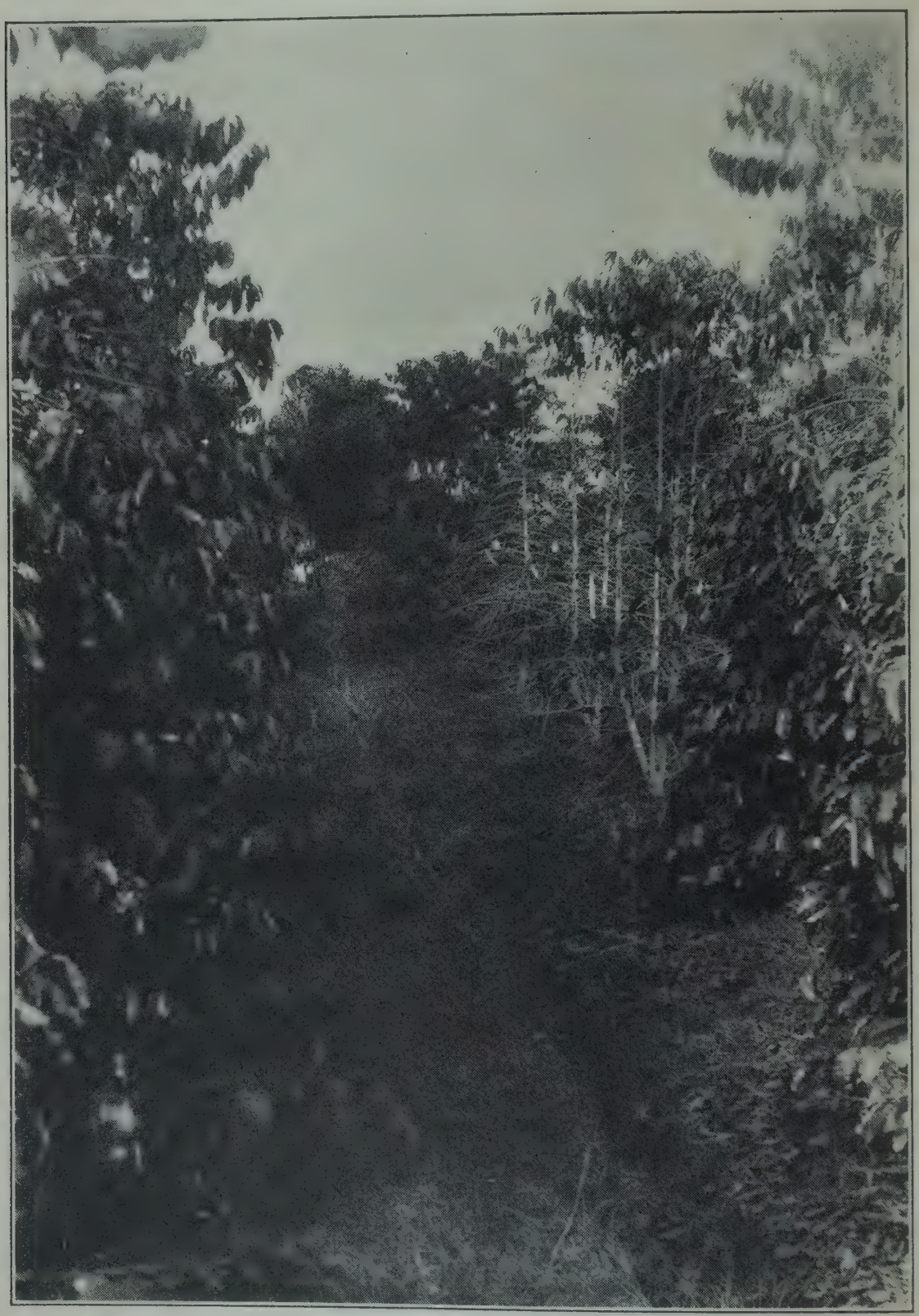

FIGURE 2.—Coffee-fertilizer experiment in Kona, Island of Hawaii. The check plat (right center) is practically denuded. Nitrogen and potash are the most needed elements in coffee fertilization in Kona

several methods tried are now clearly evident. The more drastic the pruning, the more uncertain was recovery. Drastic thinning and pruning back gave excellent results with trees already making normal

growth, but caused a sickly growth and death of some trees which had previously lacked vigor. Cutting off the trunk near the ground resulted in a slender succulent growth of shoots, many of which were not able to support their own weight and broke off readily from the old trunk. The moderately pruned plats produced a fair crop in 1932, thus resulting in the loss of only one crop due to pruning. In the severely pruned plats the vigorous trees produced only a light crop in 1932.

FERTILIZER EXPERIMENTS

Two fertilizer experiments with coffee, begun in Kona in 1930, were continued. One carried on in the Kainaliu region, where different fertilizer treatments were begun in January, 1931, showed distinct results in the next crop. The yields of coffee and the growth of the trees showed the superiority of the complete fertilizer (N–P–K) and of nitrogen and potash (N–K) over nitrogen and phosphorus (N–P), nitrogen (N) alone, and no treatment (check plat). (Fig. 2.) The

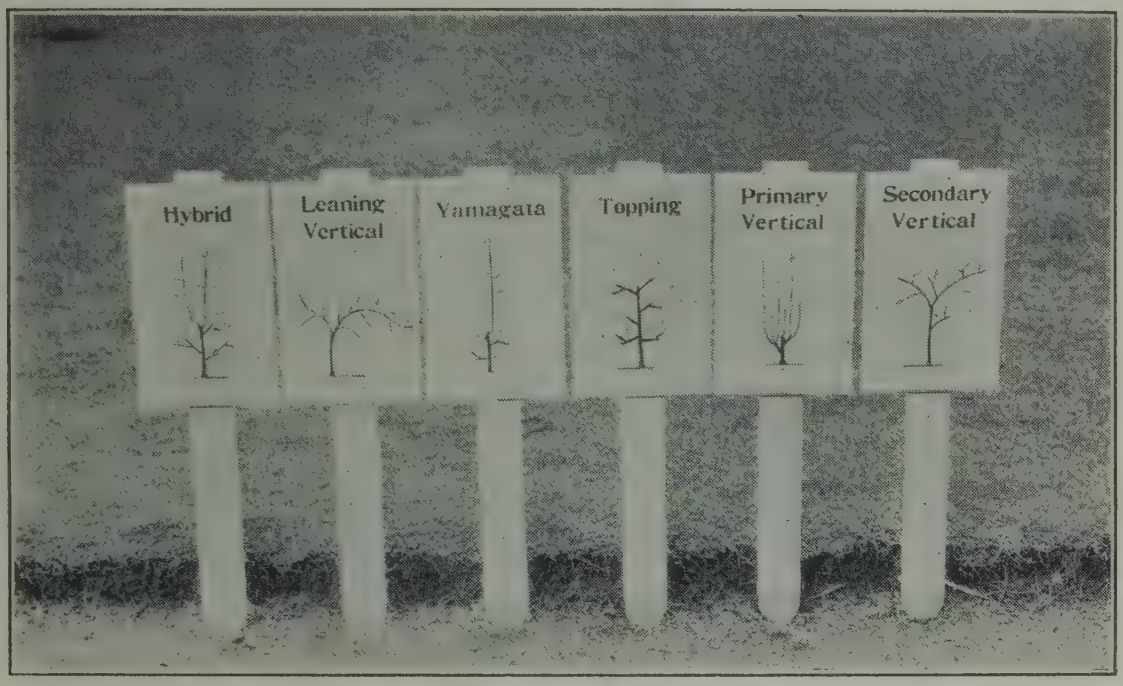

FIGURE 3.—Pruning methods used with coffee in Kona. The heavy lines indicate the permanent parts of coffee trees, and the lighter lines the parts to be removed by pruning. The efficiency of the methods is being compared

results are considered to be tentative, since the effects of sudden change in the treatment may have been extreme. The trees in the poorer plats may adjust themselves to the new treatments and recover. The response to potash is similar to that noted by McClelland (*8*) in Puerto Rico. A further substantiation of the response to potash was noted in the very high content of potash in the coffee pulp (5 to 7 per cent of potash (K_2O) expressed as percentage of dry weight) of the treated trees.

Results of experiments in the Kealakekua region, in which all the plats received uniform fertilizer and cultural treatment, strikingly demonstrated the futility of assigning to a given plat a yield value under the type of pruning (primary vertical) practiced in Kona. Coffee bears only on second-year wood and under the primary vertical method the proportion of the tree in bearing varies widely from year

to year under field conditions. A block of 104 trees was staked off for study of the correlation of tree growth with individual variation in yield.

A study of the comparative merits of different types of pruning practiced in Kona was begun in cooperation with the agricultural extension division of the University of Hawaii at two places in the Konawaena region, one at an elevation of 1,400 feet and the other at an elevation of 1,800 feet. (Fig. 3.)

REDUCING PRODUCTION COSTS

The coffee growers of Kona secure yields far in excess of the average for the other coffee-producing countries of the world, but their costs of production are also much higher. With the object of reducing

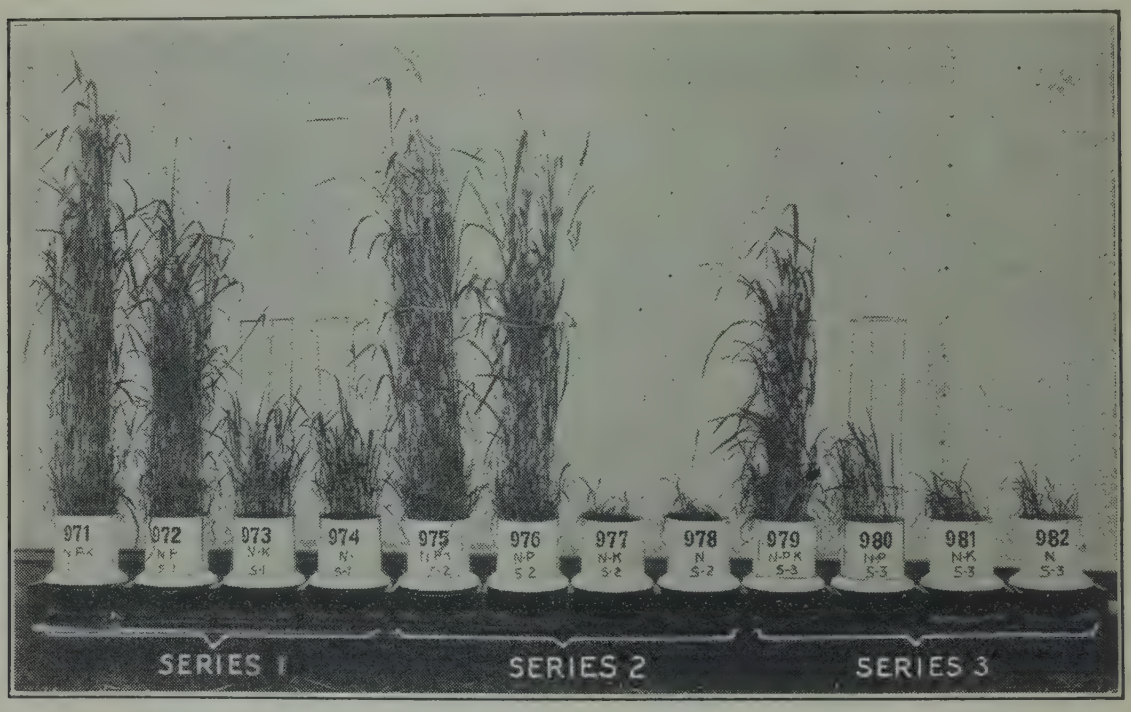

FIGURE 4.—Testing the availability of plant-food elements in rock and in scoria. Each series of four pots represents one sample. Note the excellent growth of the series 1 and series 2 plants treated with complete fertilizer and with nitrogen and phosphorus; and the markedly poor growth of the plants treated with nitrogen and potash, and with nitrogen. All series 3 plants made chlorotic growth

costs, especially those due to the use of expensive commercial fertilizers, two experiments were begun in Kona at eight places differing widely in altitude and in moisture conditions. In the first experiment, carried on cooperatively with farmers, yields from plats receiving no treatment are being compared with those receiving various amounts up to 1,500 pounds, of commercial fertilizer. In the other experiment different methods of composting coffee pulp and other available organic matter are being studied. Preliminary analyses showed the pulp from 1 acre to be roughly equivalent in value to 400 pounds of high-grade fertilizer. The pulp was high in nitrogen and in potash but low in phosphates.

MITSCHERLICH POT EXPERIMENTS

Studies were begun to correlate results from fertilizer experiments with coffee under field conditions with results obtained by the Mitscherlich pot-test method. This method has proved to be of exceptional value in determining the soil needs for sugarcane, but the

extent to which it is applicable to a perennial-tree crop like coffee is problematical. The method is being tried with a number of indicator crops, including coffee. Sudan grass was used as the indicator crop for soils from experimental plats in Kona and in Hamakua. Scoria and freshly crushed and screened rock from typical Kona lavas were also used. Usually the plants in pots receiving nitrogen and phosphorus and those receiving complete fertilizer made normal growth, whereas those in pots given no phosphorus made negligible growth. Attempts to grow second crops in the same material, either from ratoons from old crowns or by reseeding, failed except in pots receiving complete fertilizer. (Fig. 4.)

GRASSES

Analyses of grasses from 10 experimental areas on the Island of Hawaii indicated a strong positive response to lime and phosphate fertilizer applications in the grasses from Waipahoehoe and the Volcano plats. The Waipahoehoe grasses showed an increase of nearly 100 per cent in the lime and phosphoric acid content. Grasses from fertilized and unfertilized plats showed generally negligible differences both in amount of vegetation and in percentage of mineral constituents.

Grass gardens were established in many places on the Parker ranch, Hawaii, representing a wide range of climatic conditions. The ranch is cooperating in establishing plats of different grass species in each garden in order to study various questions of culture, behavior, and composition.

STARCHES

Analyses to determine the principal cations and anions of 45 starches, including commercial potato, corn, edible-canna, and cassava starch, were completed. Replaceability of the cations was studied by means of cataphoresis and by treatment with salt solutions of varying strengths. The very marked effect of the nature and the amount of the cation on the properties of the starch indicated that determining the cations, either total or replaceable, might serve as an important method of studying causes of fluctuation in the strength of commercial starches. The large amount of work required to develop a satisfactory procedure for a study of replaceability of the cations precluded a comprehensive study of this sort. Preliminary work indicated that a correlation between properties and the nature and amount of the cation exists in edible-canna starches, but not to any appreciable extent in the other species. The rapid decrease in viscosity of edible-canna starch stored for only two or three days was traced to replacement of the potash originally held in the granule with calcium. Electrotitration of a number of electrodialyzed starches gave a curve that resembled the titration curve of the neutralization of the first hydrogen ion of phosphoric acid.

REPORT ON SPECIAL CHEMICAL INVESTIGATIONS ON AVOCADO AND TOBACCO

By Leonora Neuffer Bilger, Mark Westgate, and Robert Loveland

STEROL CONTENT AND VITAMIN VALUE OF AVOCADO OIL

Preliminary studies of the oil content of the avocado were brought to a close, and an intensive study of the sterol content and vitamin value of avocado oil was begun.

NICOTINE CONTENT OF SOME TOBACCOS

Experiments were made to determine at what stage of growth of Hawaii tobaccos the nicotine content is the highest. Young, medium-old, and old tobacco leaves were allowed to dry for several days at 60° C. and then ground fine enough to pass through a 2-millimeter mesh sieve. The pulverized material was dried a second time and transferred to tightly stoppered bottles. Determinations of nicotine were made by methods of the Association of Official Agricultural Chemists (*1, p. 55*) slightly modified as follows: A weighed quantity of the prepared sample, containing about 0.5 gram of nicotine, was washed into a distillation flask made alkaline with concentrated sodium hydroxide and steam distilled into dilute hydrochloric acid until no nicotine could be detected when the silicotungstic acid test was applied. The distillate was reduced in volume on a hot plate, filtered, and made up to a convenient volume. An aliquot was acidified and treated with an excess of silicotungstic reagent. The resulting precipitate was allowed to stand until crystalline, collected on an ashless filter paper, and ignited in a platinum crucible. The residue was weighed. All determinations were made in duplicate. Table 1 records the nicotine content of four strains of Oahu-grown and one strain of Hawaii-grown tobacco.

TABLE 1.—*Nicotine in different parts of five strains of tobacco*

Strain of tobacco	Proportion of nicotine in—			Strain of tobacco	Proportion of nicotine in—		
	Young leaves	Medium-old leaves	Old leaves		Young leaves	Medium-old leaves	Old leaves
Oahu-grown:	*Per cent*	*Per cent*	*Per cent*	Oahu-grown—Contd.	*Per cent*	*Per cent*	*Per cent*
No. 2240	1.6	1.7	2.4	No. 2243	3.0	3.1	3.4
No. 2241	3.5	3.8	3.6	Hawaii-grown:			
No. 2242	2.2	2.6	2.6	No. 1	2.4	2.6	2.3

The table shows that in four of the five cases the nicotine content was lowest in the young leaves, in two cases reached its maximum in the medium-old leaves, and in two cases decreased in the old leaves.

INSECTICIDES FROM NICOTINE DERIVATIVES

Progress was made in preparing from nicotine an insecticide which kills by stomach poisoning rather than by fumigation. The need for such an insecticide in Hawaii was suggested by R. H. Marlowe, of the Bureau of Entomology of the United States Department of Agriculture. It should be characterized by high toxicity, comparatively low solubility in water, and freedom from objectionable odor and taste. A nicotine supply was obtained from a commercial nicotine-base insecticide by fractional distillation under reduced pressure. The nicotine was converted by the action of an acetic acid solution of bromine into nicotine perbromide. The latter was treated with potassium hydroxide and sulphur dioxide to produce dibromcotinine. Nicoteine (*2, p. 854; 3, p. 696; 4, p. 574*), a compound similar to nicotine and present in tobacco, is in process of preparation. Other compounds prepared, purified, and accepted for experimentation by the Bureau of Entomology were nicotine tartrate, nicotine salicylate

(*10, p. 504*), nicotine mercuric chloride, nicotine sulphate, nicotine picrate, nicotine benzoyl chloride, nicotine iodide, and nicotinic acid amide.

REPORT OF THE HORTICULTURAL DIVISION

By W. T. Pope

COFFEE

Progress was made in cultural experiments with coffee, begun in the latter part of 1930 at the Tantalus substation near Honolulu on Oahu, and at the Kona substation near Kealakekua on Hawaii. The coffees under cultivation are Hawaiian, Guatemalan, Robusta (of the robustoid group), and Excelsa, Liberica, and San Ramón (of the Liberian group).

MACADAMIA NUT

The yield of Macadamia nuts during the year was larger than ever before, because many of the younger trees came into bearing for the first time. From the seedling trees nuts of marked variation, some of them very desirable in form and in quality, were collected. Several grafted trees also came into bearing. Promising trees were selected to serve as sources of scions for vegetative-propagation experiments.

AVOCADO

Various methods of preserving avocado fruit, extracting avocado oil, and using culls and surplus fruit for feeding swine and poultry were studied at the station and by private growers. At the station 12 varieties of highland avocados from Central America and from Mexico came into bearing, and trees of both seedling and grafted stock were grown at elevations ranging from 1,000 to 6,000 feet in cooperative experiments with ranchers. Most of the introduced varieties are prolific and the fruit compares favorably with that of other varieties grown in Hawaii.

CITRUS

In a study of methods of protecting citrus trees from attacks by the fruit fly, medium-weight brown-paper bags and medium-weight cellophane bags were used to cover oranges, mandarins, and grapefruit. Two-pound bags were used for mandarins, 3-pound for oranges, and 4-pound for grapefruit. The bags were placed on nearly full-grown fruit showing no trace of yellow color, and most of them remained in good condition for four to seven weeks, at which time the fruit was picked. The bags proved to be too tough to be punctured by the adult female fruit fly, and were seldom torn. The fruit ripened without a blemish, those in the paper bags being lemon colored and those in the cellophane, orange colored.

LITCHI AND LONGAN

A modified system of air-layering the litchi was tested. Under this system the wounds, caused by girdling the small branches at points where roots were desired, were surrounded with moss alone, held securely in place. A number of 4-inch scions of the variety Kwai Mi were grafted on seedling stocks 17 months old and were 25 per cent successful. (Fig. 5.) The side-tongue method of grafting appeared to give better unions than did the other methods tried.

FIGURE 5.—Kwai Mi variety of litchi grafted on seedling stock of the same species. The side-tongue method gave the most successful union

FIGURE 6.—The giant fruit of the akala, or native raspberry plant

Seedlings of the longan (*Euphoria longana*), a near relative of the litchi, were successfully grafted with the latter.

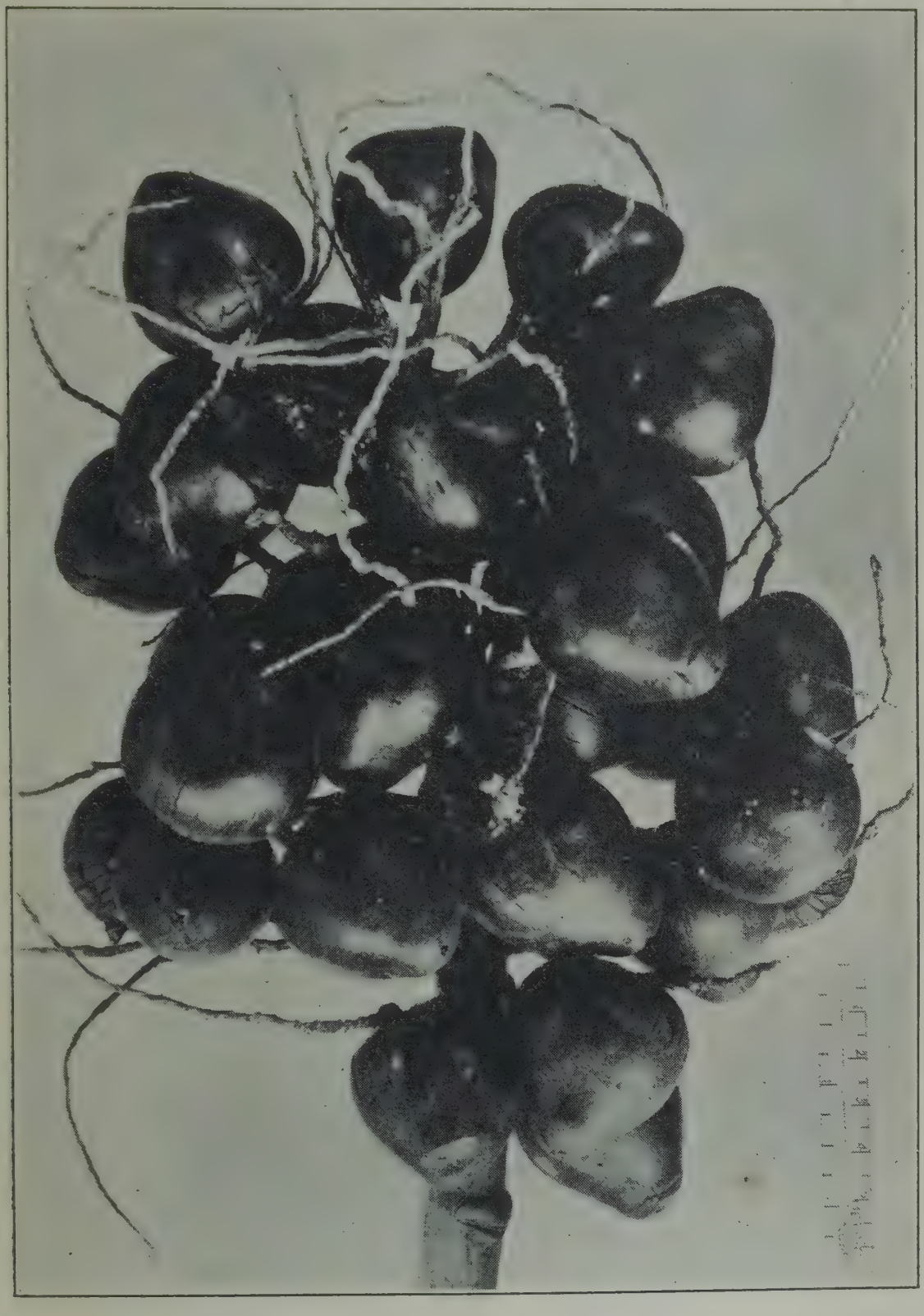

FIGURE 7.—Cluster of fruit of the pejibaye palm

AKALA OR NATIVE RASPBERRY

Further experiments were made with the akala (*Rubus hawaiiensis; R. macraei*) (fig. 6) which has been established in the two mountain ranges on Oahu at elevations of 2,300 and 3,600 feet, respectively. Several varieties of the species have been established at the Kona

substation at an elevation of 1,500 feet. A screened house was erected at the substation to protect plants for hybridization from attacks by the Japanese beetle (*Adoretus tenuimaculatus*).

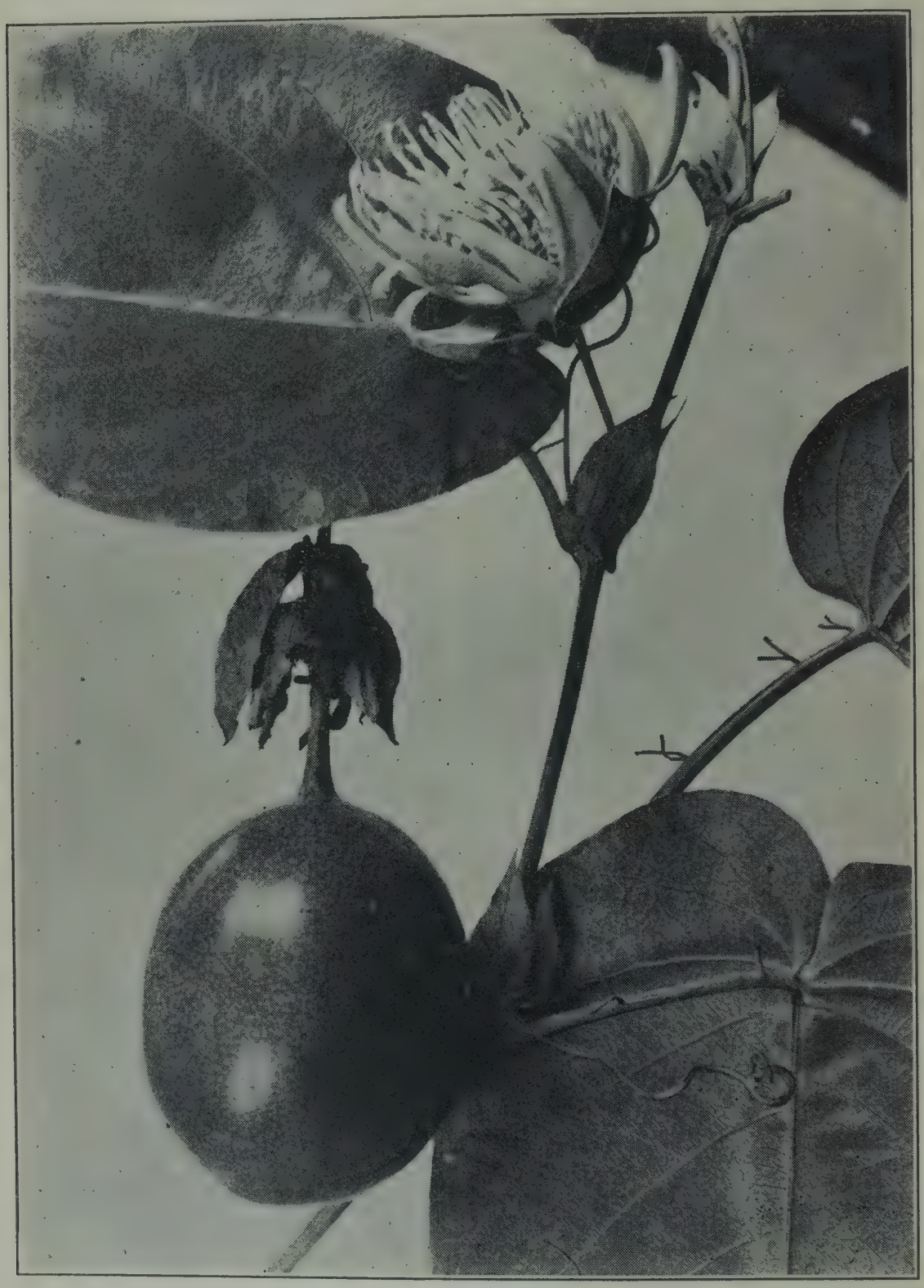

FIGURE 8.—Fruit, flower, and leaves of the sweet granadilla (*Passiflora ligularis*)

PEJIBAYE PALM

The pejibaye palm (*Guilielma utilis*), native of Guatemala, received by the station from the United States Department of Agriculture in 1924, recently came into bearing. It produced a cluster of nutlike fruits (fig. 7), from which a number of seedlings were raised. The fleshy portion of the fruit is boiled and used as food.

PASSION FRUIT

Seven species of the passion fruit, or purple granadilla, were under trial during the year, and several hundred plants were under cultivation at the central station in Honolulu and at the Kona substation.

FIGURE 9.—Papaya plant F. P. I. No. 012608. Note the fruit growing near the ground

The purple passion fruit (*Passiflora edulis*) is used for flavoring salads and sherbets, and for making beverages. The sweet granadilla (*P. ligularis*) is edible in the fresh state. (Fig. 8.)

PAPAYA

Seeds of papayas from other parts of the world were received for trial. A papaya plant received from the United States Department of Agriculture under the designation F. P. I. No. 012608, proved prolific at an early age. It bears its fruits just above the surface of the ground. (Fig. 9.)

ARBORETUM

The arboretum of economic tropical plants was enlarged and improved and made increasingly useful to investigators.

REPORT OF THE NUTRITION LABORATORY OF THE HOME ECONOMICS DIVISION

By Carey D. Miller and Ruth C. Robbins

JAPANESE FOODS COMMONLY USED IN HAWAII

A study of the manufacture, methods of preparation, nutritive value, and place in the diet of 26 Japanese foods was completed and the results, including analyses of the foods as grown in Hawaii, were prepared for publication.

VITAMIN CONTENT OF CHINESE CABBAGE

Raw Chinese cabbage (*Brassica chinensis*) was shown to be an excellent source of vitamin A, 0.0416 gram daily (0.25 gram per week) being sufficient to induce an average weekly gain of 6.5 grams in white rats, using Sherman's method. Approximately 50 per cent of the vitamin A content of raw Chinese cabbage was destroyed in the process of pickling in salt-rice-bran paste. Raw Chinese cabbage was found to be a fair source of vitamin B, 4.5 grams fed daily to standard rats resulting in an average weekly gain of 3.5 grams. Chinese cabbage pickled in salt lost a large part of its vitamin B content. A quantity of salted cabbage equal to 4.5 grams of raw cabbage was not sufficient to prevent an average weekly loss in body weight of 0.5 gram. The vitamin B content was markedly increased when the Chinese cabbage was pickled in salt-rice-bran paste. Eighteen rats, each fed 0.7 gram daily of cabbage pickled in rice-bran salted paste, gained an average of 50 grams in body weight in the eight weeks covered by the test, or 6.2 grams weekly; and 19 rats fed 5 grams daily of plain salted cabbage gained an average of 30 grams in eight weeks, or 3.7 grams per week. This indicated that cabbage pickled with the salt-rice-bran paste contains eight to ten times more vitamin B than does cabbage pickled with salt.

Investigations of changes in the hydrogen-ion concentration of Chinese cabbage showed a decrease from a mean of pH 6.38 for the fresh cabbage to a mean of pH 4.74 for the bran-salted cabbage, or from a nearly neutral point to an acidity satisfactory for the absorption of vitamin B on substances like fuller's earth and Lloyd's reagent. Undoubtedly absorption took place with the transfer of the vitamin from the rice bran to the leaf tissue. Since leaves have a negative charge and vitamin B is a basic substance, conditions for absorption equilibrium in the leaves of Chinese cabbage should be ideal. Details of the hydrogen-ion concentration determinations are shown in Table 2.

TABLE 2.—*Determinations of the hydrogen-ion concentration of extracts of Chinese cabbage*

Material	Determinations	Mean	Median	Mode	Standard deviation (distribution)	Probable error (minimum)
	Number	*pH*	*pH*	*pH*	*Per cent*	*Per cent*
Fresh leaf	28	6.38	6.28	6.3	0.36	0.046
Bran-salted water	26	4.67	4.62	4.5	.35	.046
Bran-salted leaf	38	4.74	4.63	4.5	.35	.038
Plain-salted water	37	5.55	5.44	5.5	.72	.080
Plain-salted leaf	36	4.91	4.92	4.9	.49	.055

VITAMIN CONTENT OF OPIHI

Studies of the vitamin A content of the Australian limpet, known in Hawaii as opihi (*Helcioniscus exerata; H. argentatus*), were continued. Rats fed 0.2 gram of whole opihi per week gained more than 50 grams in eight weeks. Rats fed 0.05 gram of opihi organs (largely intestines and hepato-pancreas) weekly (equivalent to 0.012 gram dry weight) gained an average of 70 grams in eight weeks, but sometimes the bladder and the kidneys of the rats showed calculi or other disorders, or the animals walked with an unsteady gait, even when the gains were good. Rats fed less than 0.05 gram of organs per week succumbed to infection before the close of the experiment. Rats fed 0.1 gram of organs weekly (equivalent to 0.024 gram dry weight) gained more than 120 grams in eight weeks. Rats fed 0.2 gram of organs per week gained 165 grams in eight weeks. Rats fed, as the sole source of vitamin A, two drops of cod-liver oil per week (equivalent to 0.05 gram) gained an average of 80 grams in eight weeks, whereas rats fed four drops of cod-liver oil weekly (equivalent to 0.1 gram) gained an average of 133 grams. The experiments indicated that the organs of opihi are a much more potent source of vitamin A than is any standard brand of cod-liver oil.

Results obtained with gonads fed separately indicated that the sperm mass is a better source of vitamin A than are the eggs. Rats fed 0.1 gram of sperm weekly gained an average of 75 grams in eight weeks; whereas others fed 0.05 gram per week barely maintained their weight, or gained less than 5 grams in body weight in eight weeks. All rats receiving 0.1 gram of egg per week lost weight in eight weeks, whereas those given 0.2 gram of egg weekly gained an average of 95 grams in eight weeks.

Four grams of opihi fed daily for eight days to rats made rachitic by feeding the Steenbock diet for 21 days gave full protection against rickets as judged by the line test. Two grams daily gave only fair protection. One gram of organs fed daily gave almost complete protection as did also the eggs. One gram of sperm daily gave complete protection. The percentage composition of opihi is recorded in Table 3.

TABLE 3.—*Composition of opihi*

Material	Moisture	Protein	Fat	Ash	Calcium	Phosphorus	Iron	Copper
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Whole	77.20	16.77	1.15	2.76	0.280	0.170	0.01337	0.00023
Egg	62.55	23.95	8.71	1.74	----------	----------	----------	----------
Sperm	75.95	20.04	2.16	2.45	----------	----------	----------	----------
Organs	75.46	12.00	----------	4.59	1.179	.163	----------	----------

VITAMIN B CONTENT OF RICE-BRAN BREAD

Bread in which 20 per cent of rice bran was substituted for white flour was made by a local baking company for the nutrition laboratory for experimental purposes. Rats fed the rice-bran bread gained an average of 60 grams in eight weeks. However, the results indicated a loss of 25 to 30 per cent of the original vitamin B value of the rice bran. Rice-bran bread sold on the local market was found to contain only half or less than half as much vitamin B as did the experimental bread tested. The rice bran used is essentially like the product technically known as "hullers." Analyses of two samples of this bran showed, respectively, water, 10.15 and 10 per cent; ash, 10.26 and 10.23; fat (ether extract), 20.42 and 20.5; protein (N × 6.25) 13.63 and 13.2; crude fiber, 8.07 and 8.29; carbohydrates (by difference), 37.47 and 37.78; silica, 0.672 and 0.775; calcium, 0.639 and 0.749; phosphorus, 2.425 and 2.43; and iron, 0.0448 and 0.0363 per cent.

The vitamin B content of local rice bran, good-quality wheat germ, and the best dried yeast that could be obtained, was compared in feeding tests. Rats, fed 0.1 gram of the bran daily, made an average gain in body weight of 64 grams in eight weeks. Those fed 0.1 gram of wheat germ daily made an average gain of 43 grams, and those fed 0.1 gram of dried yeast daily, an average gain of 37 grams.

STANDARDIZATION OF THE USE OF TIKITIKI EXTRACT

Tikitiki extract [2] probably contains very small quantities of vitamin G, in addition to vitamin B. Experiments were made to learn what was the least quantity that could be fed daily to supply the vitamin B required for good growth in rats. Rats fed 4 drops of tikitiki extract daily as a source of vitamin B gained an average of 125 grams in eight weeks, whereas five paired litter mates fed 3 drops of the tikitiki extract daily gained an average of 104 grams in eight weeks. Although rats receiving 3 drops daily made excellent growth, the dosage was increased to 4 drops for rats on a vitamin G-free diet to supply them with vitamin B. A low vitamin G content was shown when the rats were fed a vitamin G-free diet plus 4 to 8 drops daily of tikitiki extract. The rate of gain on the different amounts was practically the same.

VITAMIN CONTENT OF MOUNTAIN APPLES

Because of many inquiries about the food value of the mountain apple (*Eugenia malaccensis*), which grows abundantly in the mountainous regions of all the Hawaiian Islands, some preliminary experiments with the fruit were made. Guinea pigs fed 3 and 5 grams of mountain apple daily were found, on post-mortem examination, to have developed severe cases of scurvy. Animals fed 10 grams of the fruit daily showed no gross signs of scurvy, but histological examination of their teeth by the Höjer method proved that this amount was not enough to protect the teeth. Feeding rats 4 grams of the fruit daily as the only source of vitamin A, resulted in a unit gain in body weight of 25 grams in eight weeks. Ten grams daily was not sufficient for a unit gain of 3 grams per week in weight of rats on either a vitamin B-free or a vitamin G-free diet.

[2] The tikitiki extract was obtained from the Philippine Bureau of Science.

BIOLOGICAL VALUE OF THE PROTEIN OF PIGEON-PEA SEED

The results of feeding two lots of paired rats pigeon-pea seed meal with and without cystine, as the sole source of protein, did not correlate well with those of previous experiments, and further experiments were undertaken.

REPORT OF THE POULTRY HUSBANDRY DIVISION

By C. M. Bice

SOREHEAD (FOWL POX) CONTROL IN BABY CHICKS

Results of an experiment begun to learn how sorehead (fowl pox) (identified as epithelioma contagiosum) is transmitted to baby chicks indicated that the disease is spread by the mosquito and may be prevented by screening the runs and houses from the day mosquito (*Aedes* (*Stegomyia*) *aegypti*) and the night mosquito (*Culex quinquefasciatus*). In an experiment on the efficiency of a "live virus" vaccine, results were obtained as early as the fifth week with chicks, the fourth week with poults, and the first week with squabs.

SEX DETERMINATION IN DAY-OLD CHICKS

Efforts to find some definite sex-linked character in day-old pure-bred chicks were continued, the characters studied being voice, length of tail, length of wing, internal organs in the vent, position of chick when held by the nape of the neck or by the feet, and color of the legs and the toes in dark-shanked birds.

SUGARCANE MOLASSES FOR CHICKS

In experiments with mash and scratch rations containing different percentages of sugarcane molasses, the rations containing 5 and 7 per cent of molasses, respectively, produced good growth and economical gains, and proved more desirable than was the ration fed to the check lot or the ration containing 10 per cent of molasses.

PAPAYAS, AVOCADOS, BANANAS, AND SWEETPOTATOES FOR POULTRY

Experiments to determine the relative and the actual feeding value of avocados, bananas, papayas, and sweetpotatoes for laying hens and fattening birds were continued. Avocados were satisfactorily fed to laying hens in amounts not exceeding 15 per cent of the whole ration. Fed as a supplement to egg mash and to scratch grains, sweetpotatoes and bananas were satisfactorily used in such amounts as the birds would consume. Feeding papayas over a long period resulted in decreased annual egg production, and was detrimental to the health of the birds. Results of these experiments were published during the year (*5*).

RAISING TURKEYS IN CONFINEMENT

Experiments to learn whether turkeys can be raised economically in confinement indicated a possibility of success if the poults are vaccinated against turkey pox. The poults were confined in battery brooders until five weeks of age, when they were transferred to the brooder house. They remained in the brooder house until they were 10 weeks old and were then transferred to a semiconfined range with a shelter for roosting. When they were 16 weeks old the turkeys

were placed on a semiconfined range and roosted in the trees. Returns of more than $5 per bird above feed costs have been obtained by this method.

REPORT OF THE SOIL PHYSICS DIVISION

By H. A. Wadsworth

Work in the soil physics division during the year centered around the physical significance of the silica-sesquioxide ratios of soil colloids. Repeated analyses indicated that considerable care and universal standardization of procedure are essential if results from different laboratories are to be comparable. There was some evidence that the percentage composition of the colloidal separate collected on the filter, after the centrifuging of the supernatant liquid over the dispersed soil, depends on the speed of the centrifuge bowl, the size of the orifice admitting the liquid to the bowl, the hydrostatic head, and the duration of sedimentation.

Other studies indicated that the moisture equivalent of a soil depends on the amount and the nature of the colloidal material. In general, if similar colloids are considered, the moisture equivalent is directly proportional to the amount of colloidal material present in the soil. If different colloids in equal amounts are considered, the colloid presenting the higher silica-sesquioxide ratio provides the higher moisture equivalent. This is supported by the findings of other investigators.

REPORT OF THE HALEAKALA SUBSTATION

By H. F. Willey

At the Haleakala substation practical methods of eradicating honohono (*Commelina nudiflora*) and manienie or Bermuda grass (*Cynodon dactylon*) from cultivated fields were further developed; selective breeding of the pigeon pea was continued, 100 of the most promising strains being planted for further observation; and trials of various field crops, green-manure crops, fruits, nuts, and vegetables were continued. Distribution of improved propagating material was continued.

PLANTINGS AT THE HIGHER ELEVATIONS

At Olinda, where the elevation is 3,500 feet, plantings of many forage and root crops, fruit and nut trees, and vegetables that grow well at the lower substations were repeated. At Ukelele, elevation 4,800 feet, the plantings included pigeon peas, grasses, clovers, vetches, and cereal crops. The Ukelele plantings were largely duplicated at Mountain Paddock (5,500 feet elevation). At Puu Nianiae the elevation (6,400 feet) proved to be too great and the situation too exposed for most of the species that succeed at the lower levels. The pigeon-pea plantings succumbed and of 18 species or varieties of cultivated grasses, *Paspalum urvillei* alone grew satisfactorily.

REPORT OF THE KONA SUBSTATION

By R. K. Pahau

Substantial progress was made with the various plantings of field crops, range grasses, coffee, fruits, nuts, and vegetables at the substation established at Kona in 1930. Experiments with coffee and

with range grasses were continued in cooperation with private growers. Berry hybridization and plant acclimatization studies were made at the higher elevations.

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HAWAII AGRICULTURAL EXPERIMENT STATION
HONOLULU, HAWAII

Under the joint supervision of the
UNITED STATES DEPARTMENT OF AGRICULTURE
and the
UNIVERSITY OF HAWAII

Washington, D. C. January 1935

REPORT OF THE HAWAII AGRICULTURAL EXPERIMENT STATION, 1934

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INTRODUCTION

The continued low prices of sugar and pineapples have resulted in an increase in attention given to the problem of the wisest utilization of the marginal and submarginal lands for the growth of other crops which are not at present being overproduced. The Territory is also faced with the problem of the best use of the acreage that will probably be taken out of production of the two leading crops—sugarcane and pineapples. While the sugar and pineapple producers maintain their own experiment stations primarily for working out the problems which arise in connection with their respective industries, they have been able to render valuable assistance in various cooperative activities looking to the further development of the minor agricultural industries throughout the islands.

The development and application of an economical and rapid method of determining the fertilizer needs of diversified crops on various soil types, based on the Mitscherlich principle, has continued to constitute one of the outstanding projects of the station. Various crops, such as coffee, Macadamia nuts, potatoes, rice, soybeans, panicum (Para) grass, Sudan grass, Oriental kale, carrots, etc., have been studied by this method. Several improvements and additions to the equipment for use in the method were made during the year. The revolving type of table to hold the pots, as developed by the experiment station of the Hawaiian Sugar Planters' Association, was installed. An additional greenhouse was built. This is capable of carrying 14 revolving tables of 12 pots each (fig. 1).

FIGURE 1.—Mitscherlich pots mounted on revolving tables to secure maximum as well as uniform utilization of light. Each series of pots is placed on a separate revolving table. The tables are made to turn one revolution in about 10 minutes by means of an electric motor and a series of reduction gears. The tables are mounted on old automobile axles.

The Mitscherlich pot method offers especial promise under local conditions, as a means of studying plant nutrition and soil fertility, both from a fundamental as well as a practical standpoint. During the year a variety of crops was grown successfully in Mitscherlich pots, and it appears that nearly all of the ordinary root, tuber, leaf, or pod vegetable crops, as well as the various grasses, will grow normally (fig. 2).

A great advantage of being able to use various crops in supplementing a single indicator plant, like Sudan grass, is that the results are of immediate value without the necessity of first establishing the correlation between the indicator crop and the crop being studied. In addition, the growing of the crop itself in the pot test enables one to study specific problems of the crop not directly related to the available plant food.

Special technics are required for the successful growth of the various crops by the Mitscherlich pot method. For example, with potatoes, the whole tubers are pregerminated in coral sand until the developing stem has 2 or 3 small leaves. Uniform plants are then selected and the seed potato is cut away with a knife until about 15 grams of tissue remain. Three such plants are then transferred to each pot and allowed to grow to maturity. Frequent sprayings and dustings with bordeaux mixture, sulphur, and nicotine are required. With the succulent leaf crops, shading and humidifying with fine water spray are also necessary. With proper care, duplicates can be obtained with a difference no greater than 4 to 8 percent.

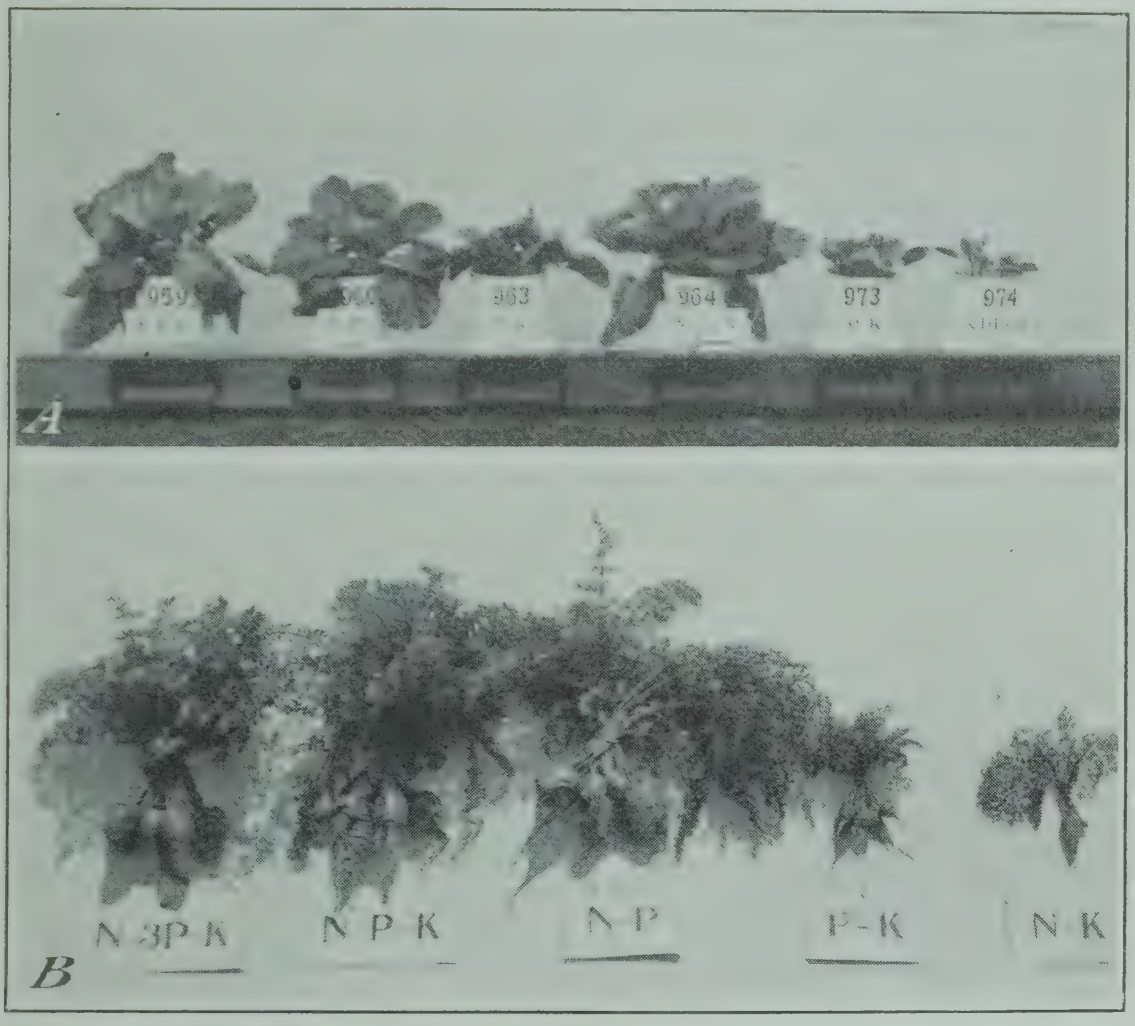

FIGURE 2.—*A*, Cabbage; *B*, carrots. A variety of vegetable crops can be grown in Mitscherlich pots. Response of these crops, in pots, to fertilizer gives promise of being a valuable indicator of field results.

With the realization that the results obtained at this stage of the work are often of qualitative value only, due to changes in technic which must inevitably result from further study, emphasis has been placed on technic rather than any attempt at close correlation with field results. Since every different crop grown in pots would require the development of a special technic, an attempt is being made to use one crop as an indicator for a group of closely related crops, the specific crop indicator being selected on the basis of hardiness, rapidity of growth, and response to fertilizer. For the leafy vegetables, Oriental kale (*Brassica oleracea acephala*) offers promise as

an indicator. It is hardy, not much attacked by insects, and grows rapidly. For the root crops, the red radish seems well adapted. It produces roots of large size in pots and grows rapidly. Preliminary tests with the various pod crops indicate that the bush beans grow better than the climbing varieties.

Continued search is being made for a general indicator crop to be used in place of Sudan grass. This grass has many desirable qualities as an indicator, chiefly uniform and rapid growth, ability to grow in very hot as well as cool weather conditions and very low experimental error among duplicates. In certain soils, however, it makes a very weak growth regardless of the fertilizer treatment. Another objection is its supersensitivity to phosphates. In many of the island soils the yield of the pot receiving nitrogen and potassium but no phosphorus is not more than 4 to 8 percent of that of pots receiving complete fertilizer (nitrogen, phosphorus, and potassium).[1] Much more exact measurement could be made of the differences between soils if a less phosphate-sensitive crop could be found. In this respect panicum (Para) grass (*Panicum purpurascens*) is being tried. For planting materials, one node with an inch section of stem is used. Ten of these are inserted into each pot without pregermination. If care is used in selection of planting material near to the vigorously growing tips, excellent growth and uniformity can be obtained. In poor soils it appears to make a more vigorous growth than Sudan grass. Tests are being made to determine how small an experimental error is possible.

Satisfactory progress was made in all of the 43 active projects of the station, although several other projects were placed on the inactive list owing to lack of adequate funds and personnel for their prosecution.

New lines of work undertaken included (1) life-history and growth-habit studies of certain grasses and legumes under tropical conditions, (2) studies as to the relative merits of various types of plantation back-yard poultry houses, (3) battery systems for laying and breeding hens, (4) artificial illumination for laying stock, (5) tree kale as a source of green feed for poultry, (6) vitamin transfer between certain plant tissues, and (7) chemical studies of the passion fruit.

Old lines of work completed or suspended included (1) the feeding of cane molasses to dairy cows, (2) sorehead control of baby chicks and poults, (3) sex determination of day-old purebred chicks, (4) value of taro and fermented poi in poultry-fattening rations, and (5) determination of the iodine content of Hawaiian sea foods.

Experiments were carried out by the agronomy division at various places throughout the Territory with range grasses, pigeonpeas, rice, green manures, forage, and vegetable crops.

The manuscript for a bulletin, giving the results of feeding cane molasses to dairy cows over a period of 8 years, was submitted for publication (see also p. 24). A bulletin showing the results of feeding cane molasses to swine was published (4).[2] An experimental

[1] In these and the fertilizer pot experiments referred to in other later places in this report, the nitrogen was, unless otherwise specified, supplied in the form of ammonium nitrate, phosphorus as sodium acid phosphate (monobasic), and potassium in the form of potassium sulphate.

[2] Italic numbers in parentheses refer to Literature Cited, p. 31.

dairy herd of 51 animals of all classes was maintained throughout the year, as well as a small herd of swine and a flock of poultry of sufficient size for the carrying out of approved experiments.

The chemical division of the station devoted its energies largely to the determination of the fertilizer requirements of the more promising minor crops (coffee, Macadamia nuts, rice, potatoes, etc.) and to the solution of technical problems arising in connection with such crops as the Macadamia nut. Special chemical investigations were also made of the iodine content of Hawaiian sea foods, as well as certain chemical constituents of avocados and passion fruit. (See also pp. 27, 28.)

In the horticultural division special attention was given to the development of an economic tropical aboretum, cultural and breeding studies of coffee varieties, akala berries, passion fruit, avocados, mangoes, etc. A bulletin on citrus in Hawaii (*6*) giving the results of 25 years' work was published, as well as a circular on the propagation of various trees, shrubs, and plants by cuttings (*7*).

The nutrition laboratory determined the nutritive constituents of numerous local fruits and made vitamin studies of certain important vegetables, fruits, and sea foods. A bulletin was published concerning Japanese foods commonly used in Hawaii (*5*).

The subject of poi manufacture and fermentation was studied by the division of bacteriology of the University of Hawaii, in collaboration with the station, and a bulletin on the subject was published by the station (*1*).

The poultry division developed the "live virus" method of sorehead control to a high degree of efficiency, and to a point where it was deemed advisable to turn the project over to a local commercial interest to furnish the vaccine to interested poultrymen throughout the islands. A station circular was issued on sorehead control. Caponizing also received attention and a circular on this subject was published (*2*). One Barred Plymouth Rock hen completed her laying year with a total of 313 eggs to her credit.

The soil physics division continued its studies of the water-holding peculiarities of Hawaiian soils.

The Haleakala substation (see also p. 30), on the Island of Maui, continued its experiments with range grasses at varying elevations, pigeonpeas, potatoes, and numerous other field crops and vegetables. The Kona substation (see also p. 31), on the Island of Hawaii, devoted its energies largely to the development of plantings of various species of coffee, avocados, mangoes, and numerous other fruits which possess promise under the local conditions. Selection work with Macadamia nuts and fertilizer experiments with coffee were also under way throughout the year. During the year an adjoining tract of 1.66 acres of arable land was acquired and is being planted to various introduced species of coffee for use in breeding work and variety tests.

The station budget for the year was $86,650, made up as follows: Territorial and university special funds, $24,000; Hatch fund, $15,000; Adams fund, $11,000; United States Department of Agriculture funds, $36,650. The last item was subsequently reduced by impoundments to the United States Treasury, which totaled $4,075. The budget for the previous year totaled $94,500.

PROJECTS

Research projects active during the year and their leaders were: Correlation between the magnitude of the sesquioxide ratio in an extracted soil colloid and soil-moisture availability (H. A. Wadsworth); breeding and selection of pigeonpeas, breeding and yield studies of forage crops, life-history and growth-habit studies of grasses and legumes under tropical conditions (C. P. Wilsie); relation of chemical composition of range grasses to pasture management (D. W. Edwards); varietal, cultural, and propagation studies of citrus, culture and breeding of Hawaiian raspberries (akala berry, *Rubus* sp.), and varietal, cultural, and propagation studies of Macadamia nuts (W. T. Pope); factors affecting chemical composition of Macadamia nuts (J. C. Ripperton); varietal, cultural, and propagation studies of coffee (W. T. Pope); rejuvenation of old coffee plantings, and nutrition and fertilizer studies of the coffee plant (J. C. Ripperton); variety tests and breeding studies of vegetable crops (C. P. Wilsie); cane molasses for dairy cows, sprouted oats for correcting breeding problems of dairy cows and brood sows, and sugar and molasses feeding of swine (L. A. Henke); control of sorehead of baby chicks and poults, sex determination of day-old purebred chicks, batteries for laying and breeding hens, artificial illumination for laying hens, gizzard-worm investigations (C. M. Bice); vitamin studies of Hawaiian foods and feeds, chemical and biological studies of protein in pigeonpeas, chemical and biological studies of the opihi (shellfish), studies of the transfer of vitamin B from rice bran to various types of plant tissues as a result of pickling them with salt and rice bran (C. D. Miller); and study of the sterol content and vitamin value of avocado oil, determination of the iodine content of Hawaiian foods, and chemical studies of Hawaiian plants, (1) poisonous plants, (2) passion fruit (L. N. Bilger).

PUBLICATIONS

The following is a list of publications of the station during the year covered by this report:

Report of the Hawaii Agricultural Experiment Station, 1933; Bulletin 68, Japanese Foods Commonly Used in Hawaii, by C. D. Miller; Bulletin 69, Cane Molasses as a Supplement to Fattening Rations for Swine, by L. A. Henke; Bulletin 70, The Manufacture of Poi from Taro in Hawaii: With Special Emphasis upon Its Fermentation, by O. N. Allen and E. K. Allen; Bulletin 71, Citrus Culture in Hawaii, by W. T. Pope; Circular 7, Capons and Caponizing, by C. M. Bice; Circular 8, Fowl Pox (Sorehead) Control by Vaccination, by C. M. Bice; and Circular 9, Propagation of Plants by Cuttings in Hawaii, by W. T. Pope.

Articles contributed by members of the station staff and published elsewhere than in the regular station series of bulletins and circulars included the following: The Nutritive Value of the Mountain Apple (*Eugenia malaccensis or Jambosa malaccensis*), by C. D. Miller, R. C. Robbins, and K. Haida (Philippine Jour. Sci. 53: 211–222. 1934); Local Crops High in Food Value, by C. D. Miller (Honolulu Star-Bull. Hawaii Farm Ann., Dec. 16, 1933, p. 50); An Inexpensive Water-Stage Register for Plantation Field Ditches, by H. A. Wads-

worth (Hawaii. Planters' Rec. 37: 92–95. 1933); Some Physical Constants for Certain Hawaiian Sugar Cane Soils, by H. A. Wadsworth (Hawaii. Planters' Rec. 37: 106–113. 1933); A Historical Summary of Irrigation in Hawaii, by H. A. Wadsworth (Hawaii. Planters' Rec. 37: 124–162. 1933); Irrigation is Highly Developed, by H. A. Wadsworth (Honolulu Star-Bull. Hawaii Farm Ann., Dec. 16, 1933, p. 11); Soil Moisture and the Sugar Cane Plant, by H. A. Wadsworth (Hawaii. Planters' Rec. 38: 111–119. 1934); On setting the Crest Elevation for the Parshall Flume, by H. A. Wadsworth (Hawaii. Planters' Rec. 38: 157–159. 1934); The Dairy Industry of Hawaii, by L. A. Henke (Honolulu Star-Bull. Hawaii Farm Ann., Dec. 16, 1933, p. 16); Pineapple Plants as Forage for Cattle, by L. A. Henke (Pineapple Quart. 4: 1–6. 1934); Territory Can Grow Dairy Feed, by C. P. Wilsie (Honolulu Star-Bull. Hawaii Farm Ann., Dec. 16, 1933, p. 18); Commercial Poultry Production and Marketing in Hawaii, by H. L. Chung, A. S. T. Lund, and C. M. Bice (Univ. Hawaii Ext. Bull. 20. 1934); Poultry Industry Grows Rapidly, by C. M. Bice (Honolulu Star-Bull. Hawaii Farm Ann., Dec. 16, 1933, p. 23); Fertilizing is Good Investment, by J. C. Ripperton (Honolulu Star-Bull. Hawaii Farm Ann., Dec. 16, 1933, p. 10); A Comparison of Legume Intercycle Crops for Pineapples, by O. C. Magistad, N. King, and O. N. Allen (Jour. Amer. Soc. Agron. 26: 372–380. 1934); More Interest in Fruit Growing, by W. T. Pope (Honolulu Star-Bull. Hawaii Farm Ann., Dec. 16, 1933, p. 36); and Research Aids Minor Industries, by J. M. Westgate (Honolulu Star-Bull. Hawaii Farm Ann., Dec. 16, 1933, p. 9).

SOILS

Continued work on factors affecting the ratio of the moisture equivalents of soils to their permanent wilting percentages indicated that the numerical value of this conventional ratio is, except in rare cases, independent of the textural classification. No significant differences in the ratios were found when Hawaiian soils were diluted with as much as 90 percent coarse silica sand. In still further dilution it is probable that the ratios would increase. The large probable errors involved with each of the determinations when large amounts of sand were used, however, made the results unreliable.

The necessity of working with small amounts of material in studying the availability ratios of the individual constituents of the soil has resulted in an indirect measure of these values. When this procedure is used samples of the soil separate in question are wetted to the moisture equivalent and brought into equilibrium with streams of air of known relative humidities. The probable wilting percentage may be deduced from the moisture contents and the surface forces involved at each of the equilibria.

No great precision may be expected from this procedure, but it promises to be a useful tool in locating the range of available soil moisture with separates that are available only in small quantities.

FIELD CROPS AND FORAGE PLANTS

RICE

The cooperative fertilizer experiments begun last year with the agricultural extension service of the University of Hawaii and with

the rice growers on the Island of Kauai were continued. The first crop was harvested and the crop replanted and fertilized for the second season's growth. The results show that for this soil nitrogen is the chief fertilizer element which is lacking. On the phosphorus-potassium plats without nitrogen the yield averaged 31 bags (100 pounds each) of paddy per acre; with nitrogen, the yield increased to 56 bags. There were slight but not significant responses to phosphorus and potassium. The nitrogen was in the form of ammonium sulphate only. In this experiment the phosphorus and potassium were applied in small furrows and the seed drilled in soon after. The nitrogen was applied about 45 days later, about the customary time for the application of complete fertilizer in ordinary practice.

Pot tests with rice, by the Mitscherlich method, using soil taken from the experimental field, were carried out in the station greenhouses. These pot experiments showed good correlation with the field results. A simple device for maintaining a constant depth of water has been found effective. A 1-quart bottle is held inverted at the edge of the pot by means of a wood-and-wire frame. The neck of the bottle extends down inside of the pot to the level at which the water is to be maintained. The bottle is filled with water once a day and the water keeps at a constant level after the manner of automatic poultry drinking fountains. Terra-cotta pots 10 inches in diameter and holding about 6 kilograms of soil are used. These are pretreated with paraffin dissolved in gasoline to render them impervious.

As an aid to the rice growers, soil samples sent in from the Moloaa, Hanapepe, and Wailua districts of Kauai were tested by the pot method for their response to the three fertilizer constituents. The results have been sufficiently conclusive to warrant the recommendation that the fertilizer practice be changed so as to maintain the nitrogen at its present level and reduce the phosphorus and potassium to one-half the present amounts. In the meantime any possible deleterious effect of this change is being studied by means of the continuous field experiments. The use of nitrogen only is not recommended, however, as indications have been obtained that the quality of the rice is adversely affected by nitrogen alone. Fertilizers are expensive, and reduction in the cash outlay in the production of rice in Hawaii is imperative if the industry is to persist.

PIGEONPEAS

Isolating and purifying strains by self-fertilization was continued. Selfing was accomplished by covering unopened buds with closely woven muslin bags and allowing the seed to ripen in the bags.

Experiments to determine the extent of natural crossing between varieties were completed. Approximately 15 percent of natural hybrids were obtained in progenies of open-pollinated plants that had been growing in rows adjacent to other varieties. A complete report of this work was submitted for publication in the Journal of Agricultural Research.

SOYBEANS

The testing of varieties was continued, emphasis being placed on those that were considered promising for green vegetable use. Yellow Biloxi Hybrid, a selection obtained through the courtesy of P. H. Kime, North Carolina Experiment Station, appeared to be quite

desirable from the standpoint of yield and quality. Two varieties, F. P. I. No. 80483 and 81780, secured through the courtesy of W. J. Morse, U. S. Department of Agriculture, gave excellent results in cooking tests for use as green vegetable beans. Twenty-one new varieties were obtained during the year from Dr. Morse for adaptation studies.

GRASSES AND LEGUMINOUS FORAGE CROPS

ADAPTATION STUDIES

Considerable attention was given to the introduction and establishment of more desirable species for pasture and green fodder use (fig. 3). Through the maintenance of a series of grass gardens at

FIGURE 3.—Guinea grass (*Panicum maximum*) in foreground; elephant grass (*Pennisetum purpureum*) in background. These coarse grasses are making a vigorous growth at 2,200 feet altitude on the windward side of Hawaii. In this section, where the sod is nearly pure Hilo grass (*Paspalum conjugatum*), these coarse grasses offer excellent possibilities in the development of fattening paddocks.

the central station in Honolulu, the Haleakala substation on Maui, and cooperating ranches on the various islands, a large number of grass and legume species were studied for adaptation to different ecological conditions. One of the striking observations made was that kikuyu grass (*Pennisetum clandestinum*) was successfully established over a wide range of climatic conditions at elevations of from sea level to 6,400 feet. Rhodes grass (*Chloris gayana*) also succeeded under a wide range of conditions, but its adaptation is undoubtedly centered below 4,000 feet elevation. Wetland trefoil (*Lotus uliginosus*) was one of the most promising legumes, growing well at from 2,000 to 4,000 feet elevation and being particularly adapted to mixed plantings, making an excellent growth with kikuyu grass.

At the higher elevations, beginning at about 3,000 feet and extending up to 6,000 feet and higher, many of the Temperate Zone

species and particularly *Lolium perenne*, *L. multiflorum*, *Festuca elatior*, *Bromus unioloides*, and *Dactylis glomerata* were very promising. At these levels the most successful legumes were perennial Australian red clover (*Trifolium pratense* var.), New Zealand white clover (*T. repens*), several vetches (*Vicia* spp.), and alfalfa (*Medicago sativa*).

Due to the commonly experienced periods of severe drought such as was prevalent in many of the ranch areas in the summer of 1933, the establishment of drought-resistant species is of particular importance. Species that showed remarkable drought-resistant qualities were Rhodes grass, giant Bermuda (*Cynodon dactylon* var.), molasses grass (*Melinis minutiflora*), pigeonpea (*Cajanus indicus*), birdsfoot trefoil, and alfalfa.

New introductions, which appeared to be worthy of more extensive trials, were *Andropogon rufus*, *Indigofera hirsuta*, and *Stylosanthes guyanensis* var. *subviscosus*. These were obtained through the courtesy of the Experiment Station for Agrostology, Deodoro, Brazil. The agricultural extension service of the University of Hawaii cooperated in these adaptation studies.

LIFE-HISTORY AND STRAIN STUDIES

Preliminary studies were made in the flowering and seeding habits of Napier and Merker grasses, two varieties of *Pennisetum purpureum*. The blooming period of a single flowering head was found to extend over a number of days, the anthers emerging about 4 days later than the stigmas. Cross-pollination seems to be the rule in this species, although some seed was produced under vegetable-parchment bags from inflorescences covered before stigma emergence. Seedlings from both open-pollinated and selfed plants of both varieties were grown. A large number of growth types and distinct morphological variations have been noted in these seedling progenies, and the selection of superior forage strains seems quite feasible. As this species is propagated commercially by asexual means, strains possessing hybrid vigor or other desirable factor combinations could be maintained readily without the necessity of obtaining them in a homozygous condition.

Similar studies were also started with Sudan grass (*Sorghum vulgare sudanense*), guinea grass (*Panicum maximum*), and panicum (Para) grass, (*P. purpurascens*).

EFFECT OF LOCATION, SPECIES, AND SEASON ON QUALITY OF PASTURE GRASSES

Bimonthly harvests during a period of 14 months of grasses from the four grass gardens located on the Parker ranch were completed. Two hundred samples were each analyzed for moisture, total and silica-free ash, protein, calcium, and phosphorus. Unusually dry weather made it impossible to get a complete series of samples from each location. The results, however, showed a number of differences in quality of the grasses due to location, species, and season, which were statistically significant. For this comparison, five grasses were used: *Phalaris tuberosa*, paspalum (*P. dilatatum*), Rhodes grass (*Chloris gayana*), tall fescue (*Festuca elatior*), and kikuyu (*Pennisetum clandestinum*). With the exception of the last named, the grasses were clipped close to the crown of the stool every 2 months

so that the samples represented a 2-month growth. In the case of kikuyu, a creeping grass, only the fresh growing tips were taken for analysis. Most striking was the effect of location on the phosphorus content of the grasses. The poorest location (the leeward, dry grass garden) was scarcely 30 percent of the best in this constituent. The percentage of calcium was also affected, the windward, wet location being the poorest. Protein, on the other hand, was remarkably constant for the four locations.

Using the so-called "pairing method" of statistical analysis, it was possible to show significant differences among the five species. Season, too, seemed to have an effect, the poorest quality being found during the season of least growth, i. e., the cold winter months. Of the three factors—location, species, and season—the first named had much the greatest effect on the mineral content. The differences between the grass species on this basis of comparison were generally not great.

QUALITY OF FORAGE AS AFFECTED BY FERTILIZERS AND STIRRING THE SOIL

Former experiments with top-dressing of pastures with nonnitrogenous fertilizers showed a general lack of response except in cases of extreme deficiency. This, together with the oft-noted stimulation resulting from plowing and disking of the pasture sod, suggested the possibility that the fertilizer was not carried down to the grass roots or that the sod required stirring in order to stimulate the absorption of the fertilizer. To test this hypothesis, an experiment was begun on Grove farm, Kauai, comparing the effect of fertilization alone, fertilization plus plowing, and plowing alone. The fertilizer consisted of 1,000 pounds of phosphate fertilizer per acre—600 pounds as raw rock and 400 pounds as superphosphate. The area being used is one that is reputed to produce forage deficient in phosphates.

FRUITS, VEGETABLES, AND NUTS

AKALA OR NATIVE RASPBERRY AND OTHER RUBUS SPECIES

During the past year this work has included a study of both native and exotic species. Practically all but the most recent introductions are growing in a wild state as a part of the natural vegetation. The kinds of *Rubus* most commonly found consist of the akala (native raspberry) of two species, *Rubus hawaiiensis* and *R. macraei*, the thimbleberry (*R. rosaefolius*), and several varieties of American blackberries, dewberries, and raspberries.

The akala grows in moist land at altitudes ranging from 2,500 to 7,000 feet. In places, the two species form the main under-shrubbery of the forest and occasionally occur in mixed stands. The plants are eagerly devoured by livestock, and in range sections only plants in places inaccessible to the livestock may be found in fruit. Where the animals are kept out, as in new forest reserves, the plants spring up quickly and in great numbers as root suckers and seedlings. Seeds no doubt are disseminated to a considerable extent by birds. The stems and branches of the current year's growth of both species are more or less covered with tender green spines, but these are shed with the bark during the growth of the

second year as the stems become woody. The plants are not regarded as undesirable.

Rubus hawaiiensis is of uprignt form and often reaches a height of 8 to 10 feet. The individual plant usually consists of a clump containing several upright woody stems which continue to grow for a number of years, and in favorable conditions each may attain a diameter of 1.5 or 2 inches. Ordinarily, the fruit begins to ripen by April 1 and may be found as late as July. At maturity, the fruit averages 1.25 inches in diameter and occurs in two varieties, the dark purple and the yellow. The color of the fruit, however, is the only character distinguishing them. The flavor is often fair. *R. macraei* is a deciduous form with long arched canes with spines and scaly bark very similar to *R. hawaiiensis* but is later in coming into fruit, its season of bearing being from mid-July to November. The fruit averages 1 to 2 inches in diameter and is of a blue-black color and possesses various degrees of bitterness. These two species have been found on all of the larger islands except Oahu, but in this experiment was transplanted to 3,500 feet altitude on Oahu from the Island of Hawaii. Their cultivation has been undertaken at the Kona substation, 1,500 feet altitude, but the plants have not been vigorous and have failed to fruit.

The thimbleberry (*Rubus rosaefolius*), indigenous to southeastern Asia and the Philippines, is of early introduction into Hawaii. It now grows as a part of the natural vegetation in many places from near sea level to an altitude of 6,500 feet. The attractive but insipid light-red fruit is edible but the species is generally considered a pest. The canes and branches are thorny and the plants utilize considerable land in pastures and elsewhere which is desired for other plants.

Blackberries of several varieties, introduced many years ago, have formed thickets in several parts of the Territory. Although the fruit is used considerably, there is fear that they may soon become a very undesirable pest. The exact species has not as yet been satisfactorily determined. There are evidently two varieties, the most common being an evergreen type occurring on the Islands of Hawaii, Maui, and Oahu, and a deciduous form near the village of Holualoa on the Island of Hawaii. A few plants of the mammoth thornless blackberry were recently introduced, and, with two varieties of the dewberry, are in cultivation at the central station in Honolulu. The latter consists of a few plants each of the Youngberry and the Gardena dewberry. These, and the mammoth thornless blackberry, are being cultivated at several different elevations to determine their action under Hawaiian conditions. Former introductions of raspberries have failed to endure. Recent introductions by the station have been made from the mainland of the United States. These American varieties also have mostly died. One species from the Philippines, *R. niveus*, and a wild form from Java, have made considerable vigorous plant growth but as yet have shown but little inclination to fruit.

Not finding sufficient blossoms in the trial plats for hybridizing in April 1934, it was decided to collect pollen from blackberry plants in the Kilauea section of Hawaii and from another variety growing in the edge of the woods at an altitude of about 2,000 feet near

Holualoa, North Kona, and from the wild thimbleberry (*R. rosaefolius*) in South Kona, Island of Hawaii. The flowers were collected on April 19 and taken to a forest reserve on Mount Hualalai at 6,000 feet, where there is a good stand of *R. hawaiiensis* and *R. macraei*. Forty flowers of the native species were hand-pollinated and covered with cellophane bags, which, at that high, cool location in the partial shade of the woods, proved very satisfactory. Thirty-two days after pollination, a considerable number of the hybridized flowers had developed into fruit.

POTATOES

Variety tests of potatoes conducted on Oahu and Maui continued to show the superiority of the Bliss Triumph among the early red-skinned types and British Queen among the white varieties. The new variety, Katahdin, grown from Oregon seed stocks, gave excellent results in preliminary trials.

Nine varieties of potatoes were imported from New Zealand through the courtesy of the New Zealand Government Pure Seed Station. These were compared with Bliss Triumph and Earliest-of-All varieties grown in Hawaii. Only one of the New Zealand varieties gave a yield that compared favorably with the American varieties, and this (Up-to-Date) produced at the rate of 129 hundredweight per acre as compared to Waimea-grown Triumphs that produced 160 hundredweight per acre. These New Zealand varieties did not seem to be well adapted to Hawaiian conditions. Although all varieties were certified in New Zealand, the percentage of virus diseases was quite high in the field plats, showing, perhaps, that under Hawaiian climatic conditions the development of those diseases is more pronounced than under the cooler conditions of New Zealand.

Experiments on the production of disease-free seed stocks of the Triumph variety in Hawaii indicated that excellent seed potatoes could be grown at high elevations (5,000 feet) if the fields were carefully rogued for all diseased and weak plants. Yields obtained from such locally produced seed were higher (in variety tests) than those obtained from any other seed lot, including mainland certified seed of the same variety.

Three potato-fertilizer experiments were conducted on the Island of Oahu in cooperation with the local pineapple industry (fig. 4). These experiments consisted of comparisons of 9 treatments with 10 replications each. The treatments included 4 different amounts of phosphorus, in form of superphosphate, 2 of nitrogen, in form of ammonium sulphate, and only 1 of potassium, in form of potassium sulphate. The results showed in all cases a marked response to increments of phosphorus even in amounts as high as 1,000 pounds of superphosphate per acre. The plats receiving ample nitrogen and potassium but no phosphorus gave a yield of about 40 bags (100 pounds each) of potatoes per acre, while the yield when phosphorus was applied averaged 110 bags per acre. The response to nitrogen was variable, depending on the soil, the average being an increase of about 25 bags per acre over the phosphorus-potassium plats. Response to potassium was nil in all cases. For this type of soil, which is the ordinary red upland soil commonly used for pineapples,

a fertilizer mixture containing 12 percent nitrogen, 30 percent phosphoric acid (P_2O_5), and 6 percent potash (K_2O), at the rate of about 800 pounds per acre, is recommended. On the basis of the relatively low cost of fertilizer as compared with the other costs incident to growing potatoes in Hawaii, this high rate of application appears justified on the basis that it insures sufficient plant food for a bumper crop, given favorable weather conditions.

SWEETPOTATOES

Seventy varieties were tested for yield and 20 of these were used in cooking tests. Many were found to have rather poor quality for baking, being dry and tasteless. A few, Laupahoehoe, Madeira,

FIGURE 4.—Potato-fertilizer experiment on lands of a local pineapple company. Note the small growth of the nitrogen-potassium (no phosphate) plat in the center foreground and right center in the background. Spraying with bordeaux mixture is being done with a type of machine used by the local industry for spraying the pineapples with iron sulphate.

Japanese Brown Sweet, Pumpkin Yam, and several new selections from the Union of Soviet Socialist Republics had excellent cooking qualities. A collection of Hawaiian varieties has been introduced at the station through the courtesy of J. S. B. Pratt, of Eleele, Kauai.

SWEET CORN

Due to the susceptibility of sweet-corn varieties to the corn-stripe disease, efforts are being made to develop resistant sweet-corn hybrids. Guam corn shows little injury from this disease and is being used in the breeding work. Crosses have been made between Guam and Surcropper Sugar, Narrow Grain Evergreen, Country Gentleman, and Golden Cross Bantam. So far there has been some evidence of disease resistance in the Guam sweet-corn hybrids, and the work is to be continued. In these crosses many types intermediate between the true starchy and sugary types have been noted.

CABBAGE

Two field experiments with Copenhagen Market cabbage were made in the volcano district, Island of Hawaii. One was on virgin soil, to determine the requirements for nitrogen, phosphorus, and potassium. The first crop showed a marked deficiency of both nitrogen and phosphorus, even though it was recently cleared forest land. An earlier experiment on a nearby cultivated area had shown a good supply of phosphorus in the soil. The discrepancy was, in all probability, due to the residual effect of previous fertilizations and points to the desirability, wherever possible, of conducting all field experiments for a period of two crops in the same rows. Especially is this necessary in the gardening districts where very heavy applications of fertilizer are made. It has been found that the second crop will show very marked deficiencies, which were completely masked in the first crop. The other experiment in this district is designed to determine the economic rate of application of a complete fertilizer for cabbage.

The soil of the volcano district is made up of volcanic ash from which certain of the fertilizer elements leach readily. Farmers, for that reason, find it necessary to apply fertilizer as many as three or four times for a single crop of cabbage. An experiment has been planned to study the feasibility of using organic forms of fertilizer instead of the cheaper mineral forms.

At Waimea, Island of Hawaii, a fertilizer experiment with cabbage was carried through the second crop. The first crop showed little deficiency of nitrogen, phosphorus, or potassium. The second crop showed a distinct need of phosphorus with moderate deficiencies of both nitrogen and potash. The third crop in the same lines is now being grown. In connection with each of these field experiments, pot tests were made with Sudan grass, as well as cabbage and kale. A very acceptable correlation appears possible with both Sudan grass and kale. The field experiments were made in cooperation with the agricultural extension service of the University of Hawaii.

LIMA BEANS

Several selections of Hopi lima beans, introduced through the courtesy of W. W. Mackie, University of California, gave excellent yields as compared with Fordhook bush and Henderson bush varieties. The Hopi lima strains showed a definite perennial tendency and bore two good crops of seed. Two of these strains showed resistance to the root-knot nematode, while the others, as well as the standard varieties, were very susceptible.

LETTUCE

The breeding of lettuce for adaptation to low elevation conditions was continued. Hybrids between Mignonette and Selection 1801 were promising, showing the fine heading characteristics of the Mignonette parent and the larger size of the 1801. The season was not favorable for the production of solid heads of good size, but an excellent crop of seed was harvested for future plantings.

MISCELLANEOUS CROPS

Variety tests were conducted with taro (*Colocasia esculenta*), cassava (*Manihot utilissima*), peanuts (*Arachis hypogaea*), tomatoes,

and garden beans. Several species of *Cracca* were grown to study the growth and adaptations to local conditions, and are being used for the extraction of rotenone, tephrosin, and other compounds for insecticidal use.

MACADAMIA NUT

PROPAGATION AND CULTURE

In cooperation with interested growers, several selections of Macadamia trees which have good horticultural records were made. These trees are vigorous and prolific, and the nuts are first class as to size, roasting qualities, and flavor. They are to be maintained as a source of graft wood for the development of true varieties by vegetative propagation.

FIGURE 5.—A recently transplanted grafted Macadamia-nut tree 30 inches high at Kona substation.

The grafting work previously started in an attempt to standardize varieties of the Macadamia nut has proved successful. In brief, the methods worked out are as follows: Macadamia seedlings are grown in the field in rows at right angles 2 feet apart each way. When the seedlings are 18 to 20 months old, they are grafted at about 2 feet from the ground, the union being of the side-tongue graft, details of which are given in a recent circular of the station (*8*, *p.* 8). The method gave about an 80-percent success, and by January 1933, and during each succeeding month, a few trees were dug up and transferred to a permanent place in other fields. The transplanting of the young Macadamia tree is often considered to be difficult. Figure 5 shows one of the trees several weeks after it had been reset in the station orchard.

Seedling trees grafted at 2 feet from the ground may have their crown branches formed anywhere from 3 to 4 feet above ground, which is a very satisfactory height for them in localities subject to considerable wind. Grafted trees tend to be slightly dwarfed, which is a good form for orchard trees, and such trees also tend to come into regular bearing at 6 to 7 years of age. Seedling trees are somewhat erratic and may not bear until 10 or 15 years of age.

At the present time there are approximately 20,000 Macadamia-nut trees distributed mostly among nine plantations in the Territory of Hawaii, and practically all of these are seedlings. The present crop

of Macadamia nuts is a miscellaneous collection varying in many ways and requiring much sorting and selecting until only a comparatively small quantity of high-grade nuts remains for marketing in competition with other kinds of nuts, most of which come from well-organized industries where the growers use only grafted varieties.

HARVESTING AND MARKETING

The ideal sequence from the harvesting of the Macadamia nut to the final cooking and packaging is to husk as soon as the nuts are gathered, then store for 3 or 4 weeks at a temperature not greatly in excess of 75° to 80° F. with good air circulation. Under conditions of ordinary humidity (70 percent saturation), the kernels dry in 3 or 4 weeks to 3–4 percent of moisture, without molding or development of off-flavors. Cracking, cooking, and packing can proceed at once. Excessive temperatures, high humidity, poor air circulation, or too long a period of storage after air-curing are to be avoided.

The main bulk of the crop drops during a 4- or 5-month period, beginning with July. This necessitates storage of the nuts after they are harvested and cured. An experiment was begun to study (1) storage as uncracked nuts versus extracted kernels; (2) temperature of storage—20°, 32°, 40° F., ordinary room temperature, and hot-room temperature; (3) moisture content—air-dry versus dehydrated nuts; (4) time of storage—3 months, 6 months, and 1 year; (5) storage in sealed versus open containers; and (6) storage as roasted nuts versus storage as cured nuts with subsequent roasting. The samples stored for 3 months were opened, roasted, and compared as to texture and flavor. The most important observation made was that the nut absorbs odors from the cold-storage room readily, the extracted kernels more so than the nuts in the shell, but even the latter could not safely be stored with miscellaneous vegetables or other food products. This same tendency to absorb odors has been observed in the use of various fumigants to prevent weevil infestation. The low temperatures had no apparent effect on the nuts after 3 months in cold storage.

As a factory procedure, dehydration of the extracted cured kernels at about 180° F. for several hours until the moisture content is reduced to about 2 percent, with subsequent storage in closed tins at 40° F., is apparently the most satisfactory method. This effectively kills the weevils, prevents molding or rancidity, and permits storage for protracted periods at a nominal cost. Since the Macadamia nut will be sold almost entirely as a roasted product, the storing of the extracted kernels appears to be the most feasible procedure.

One hundred and seventy-eight samples of Macadamia nuts representing all the principal localities in Hawaii where such nuts are being grown, and including both smooth- and rough-shell varieties, were graded as to quality. Monthly samples were taken from each tree throughout the harvesting season when practicable. Otherwise 1 or 2 samples per tree were tested. Through the cooperation of a local Macadamia-nut company, the entire series was run through the regular factory procedure. This consisted in (1) putting the nuts through a centrifugal "gun" which jars the kernel free inside the shell, (2) sizing the nuts into large, medium, small, and culls

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(nuts too small to be accepted at the factory), and (3) extracting the kernel by means of a large-scale power cracking machine. Differences among the various samples in any of the three steps can thus be translated into terms of commercial significance.

Results of the year's tests tend to bear out previous observations that, as compared with the rough-shell variety, the smooth-shell nuts are of greater uniformity with less tendency to drop as immature nuts. It cannot be said with certainty that this is due entirely to variety since the smooth-shell and rough-shell samples come from different localities. The early drop of nuts from any given tree is usually high in immature nuts. The main crop, which falls during a 2- or 3-month period, is of the best quality. The late drops are of much better quality than the early drops.

It is especially encouraging to note the excellent quality of nuts from new seedlings growing among coffee in the Kona district. The interplanting of Macadamia and coffee would seem to have some very obvious advantages. Coffee does well under partial shade, so that interplanting with Macadamia at intervals of, say, 50 feet would not appreciably detract from the coffee yields for a long time, and the Macadamia could be brought to bearing age at a nominal cost.

Fertilizer experiments both in the field at Keauhou, Kona, and in pots at the Pensacola Street station, Honolulu, have been continued. It is too early to observe any effects of the different treatments.

COFFEE

VARIETAL STUDIES

The coffee trees used in the present coffee experiments have been in part in cultivation on the Islands of Oahu and Hawaii. The old grove of about 125 trees, located at the Tantalus substation, Island of Oahu, altitude 1,000 feet, which was planted some years ago for varietal study, has also been a source of propagating material. This grove consists of Hawaiian, Liberian, and a few trees each of *Coffea excelsa* and *C. robusta.* The early planting of the present experiment, made in 1931, consisted of 2-year-old trees of Hawaiian and Robusta varieties which are utilized for study of both cultural methods and habits of growth (fig. 6). In 1934 these trees produced a fair crop. The propagating work has been done mostly at the central station in Honolulu.

The work of accumulating seedlings and grafted stock has been in progress during the early part of 1934 for more extensive cultural trials in a new field of 1.66 acres, recently acquired, adjoining the Kona substation. The planting was begun with the early showers of the wet season, which began early in February. The kinds of coffee selected have been based upon the merits of each, as shown either in Hawaii or some other coffee-growing country. These merits or characteristics are vigor, productiveness, quality of grain, and root resistance to some sort of adverse soil conditions, particularly when employed as rootstocks following vegetative methods of propagation.

The names of the coffee varieties, origin, unusual characteristics, and arrangement of planting in the new field at the Kona substation are as follows:

Hawaiian (*Coffea arabica*), Arabian group; nativity, tropical Africa, but reaching Hawaii from Brazil. This variety proved adaptable to Hawaiian conditions; quality very good; planted in experimental field, one row, 22 selected seedling trees; one-half row, 11 grafted trees, scions united with Robusta rootstocks; one-half row, 11 trees grafted on Liberian rootstocks.

FIGURE 6.—Hawaiian coffee (*Coffea arabica*). Four-year-old tree in fruit, 7 feet high, at the Kona substation, Island of Hawaii.

Guatemalan (*C. arabica*), Arabian group; nativity, tropical Africa, but introduced from Guatemala; adaptable to Hawaii; quality very good, probably due to long period of seed selection in a country very favorable to its growth; one row, 23 selected seedlings; one-half row, 12 seedlings for pruning experiments; one-half row, 11 trees selected scions on San Ramon rootstocks; one-

half row, 10 grafted trees on Robusta rootstocks; one-half row, 13 trees on Liberian rootstocks.

Maragogipe (*C. arabica*), Arabian group; originated in Brazil; introduced into Hawaii from Java. It differs from other Arabian coffees in having larger cherries and beans than other varieties of the Arabian group; it also has a late-ripening season. In the field there is one row of selected seedlings for varietal test; one-half row for pruning test; one-half row for scion wood; one-half row, 11 trees grafted on Robusta stocks; one-half row, 12 trees grafted on San Ramon stocks.

Robusta (*Coffea robusta*), Robustoid group; native of Congo, Africa; received in Hawaii from Java, Mozambique, and Panama. It was the main coffee grown in Java in 1920, where it is also extensively used as a rootstock said to be very resistant to adverse conditions. One row of seedling trees for seed production; one row, 22 trees for scion wood; one-half row, 11 trees on Liberian stocks; one-half row, 11 trees on San Ramon stocks.

Padang (*C. arabica*), Arabian group; Sumatra variety. The beans are next largest to Maragogipe. One row of seedling trees for trial production; one-half row, 11 trees on Robusta stocks; one-half row, 11 trees on Liberian stocks.

San Ramon (*C. arabica*), Arabian group; originated in Central America from where it was received in Hawaii; a dwarf variety, fairly true in this respect from seeds; very prolific and late in maturing. One row of seedling trees for production; one-half row, 11 trees on Maragogipe stocks; one-half row, 10 trees on Liberian stocks; one row of seedlings for pruning experiments.

Excelsa (*C. excelsa*), Liberian group; discovered in western Africa. This variety ripens the main part of the crop in spring—cherries do not fall on ripening. The plant is very resistant to adverse soil conditions. One-half row for production; one-fourth row, 6 trees grafted on Liberian stock; one-fourth row, 6 trees on Robusta rootstocks.

Columnaris (*C. arabica*), Arabian group; supposed to be of Javan origin. The trees become large and vigorous and produce heavy crops. It has been known to produce well at an altitude of 3,000 feet. One row of seedlings for trial production and one-half row for rootstocks on which to graft several other varieties have been planted.

Miscellaneous varieties. One row of different kinds of graft unions; also grafts made at different seasons of the year.

PROPAGATION STUDIES

The coffee-grafting work of the past year has included propagation of nursery stock. The seedlings have been germinated in a medium of equal parts of rich loam containing considerable humus and coral sand in ordinary germinating flats of about 3 inches in depth. The seedlings in these flats require from 3 to 4 months' growth to attain sufficient size for transplanting into individual 4-inch containers, which are sufficient for another period of 4 to 6 months' growth. They are then transplanted to 8-inch containers, where they remain without serious root confinement for another 6 months. Within 18 months of growth from germination, the seedling is usually about 1.5 feet high and has a stem diameter near the base of about five-eighths of an inch. The seedlings are grown in the slat house with such other tropical plants as require partial shade. The conditions of coolness and humidity, which are desirable for vigor and uniformity of growth, particularly during the time the stock and scion of the graft are uniting, are thus maintained.

A simple form of graftage which has been employed to some extent in some other countries has been used very successfully at the Hawaii Station with seedlings of either the Liberian or Robustoid group. These kinds of coffee are known to have vigorous roots which are generally resistant to unusually cool or wet soils, attacks of nematodes, and possibly to some other soil disorders. The young seedlings of a month or 6 weeks' growth are transplanted from the

propagating flat to individual 3.5-inch plant pots. After having become established in these containers, which requires about 2 months, the seedlings may be cleft-grafted without the removal of the foliage. In making the union, the stem is cut off a little above the first or second pair of leaves and then split down through the middle for about an inch. The young, comparatively tender scion of about the same diameter and of the desired variety is prepared by cutting the basal end into a narrow wedge as long as the cleft and into which it is inserted and the union bound tightly with a flat strip of moistened raffia. This method of grafting has been successfully employed this year with coffee seedlings up to 18 months old in 8-inch plant pots.

Where very small seedling plants are grafted the small size of stem naturally requires small scions which are only obtainable as seedling scions, but where such scions are from desirable seedling varieties it proves satisfactory. Rootstock seedlings, having a diameter of 0.5 inch or more, however, will unite with larger scions of trees of known quality, thereby producing true varieties.

PRUNING EXPERIMENTS

The two cooperative experiments, begun in 1932, comparing different pruning systems, were continued. These systems are: (1) Secondary vertical, in which much of the plant is permanent and the bearing surface is high up in the top; (2) multiple vertical, in which only 2 to 4 feet of the stump is permanent and new vertical branches are brought out periodically; (3) topping system; (4) modified topping system, in which the base of the plant is like that of the topped system and the top is similar to that of the multiple vertical; (5) tall vertical system in which the verticals are retained for a longer period than in the multiple vertical; (6) leaning vertical system, in which the verticals are maintained in a horizontal position. Plants pruned by these different systems are now showing marked differences in appearance and the results are becoming increasingly valuable as a means of comparing the different systems under identical conditions of soil and climate.

The systematic pruning experiment, in which a study is being made of the feasibility of removing and forcing out the same amount of wood each year, was continued. From the standpoint of field experimentation, such pruning offers possibilities of reducing the tremendous fluctuation in yield of a single tree from year to year which occurs with the ordinary pruning methods.

Girdling, as a means of insuring the development of a low-setting vertical on the old vertical to be removed the following year, was successful in about 90 percent of the girdles. The shoots, which set on, did not always develop rapidly enough to be of appreciable size at the end of the season. There is also some evidence that girdling affected the size of the cherry and the amount of die-back on the girdled vertical. This method requires further experimentation to determine its value.

The coffee die-back experiment was continued. The purpose of this experiment is to limit the amount of bearing of the young tree during the period when excessive bearing often gives the plant a set-back of several years. Under the climatic conditions of the

1933 season, die-back was not apparent in any of the plants in the young orchard in which the experiment is located.

EXPERIMENTS IN HAMAKUA

Fertilization of the coffee-rejuvenation experimental plats was discontinued, but periodic inspections were made of the new growth and systematic pruning was carried on. The moderate pruning method, whereby the old trunk, thickened laterals, and a small amount of young branches are left on the plant, appears to be the best method of renewing growth on the run-down plants. While this is a tedious procedure, it results in a loss of but one crop and can be used on plants of low vitality, where the more drastic stumping would probably kill a considerable number. The so-called "parrot-stick" method, whereby all growth is removed to within about 12 inches of the old trunk, is likewise too drastic to be safely used on run-down plants. Response to fertilization in the Hamakua section is variable. In some fields good increases result; in others there appears to be ample plant food. Improper regulation of shade is often a limiting factor in production in this district.

EXPERIMENTS IN KONA

Results of the 1933–34 harvest of the Kainaliu fertilizer experiment gave 206 bags (100 pounds each) of coffee cherry per acre for the complete-fertilizer (nitrogen-phosphorus-potassium) plats, 202 bags for nitrogen-potassium plats, 51 bags for nitrogen-phosphorus plats, 61 bags for plats receiving nitrogen only, and 65 bags for the check plats. The complete fertilizer used in this experiment is 2,000 pounds per acre of a mixture containing 8 percent each of nitrogen, phosphoric acid (P_2O_5), and potash (K_2O). These results are very similar to those of the two previous seasons.

The nitrogen-phosphorus and nitrogen plats made a fairly good growth of new wood during the previous season, and it seemed possible that the 1933–34 crop from these treatments might approach those of the high-yielding nitrogen-phosphorus-potassium and nitrogen-potassium plats. It became evident as the season progressed that potassium plays an important part in the development of the fruit. In spite of a normal set of fruit, die-back became increasingly evident in the nitrogen-phosphorus and nitrogen plats. The amount of cherry which died back was collected and weighed separately from the normal cherry. In the nitrogen-phosphorus-potassium plats, die-back was at the rate of 0.2 bag per acre; in the nitrogen-potassium plats, 0.8 bag; in the nitrogen-phosphorus plats, 6 bags; in the nitrogen plats, 12 bags; and in the check plats, 4 bags per acre.

Pot experiments at the Pensacola Street station, Honolulu, using coffee seedlings grown in soil from the Kainaliu experiment, show very strikingly this same difference in the functions of phosphorus and potassium in the nutrition of the coffee plant. The trees are 20 months old and fruited for the first time this season. Previous to blooming, the nitrogen-phosphorus-potassium and nitrogen-phosphorus trees were nearly equal in size and vigor, with the nitrogen-potassium plants far smaller. With the appearance of fruit buds, the nitrogen-phosphorus plants began to drop many of their leaves, and scarcely any blossoms opened. The nitrogen-phosphorus-potas-

sium plants blossomed freely and set fruit normally. The nitrogen-potassium plant is small in size but otherwise normal and sturdy. This suggests the possible advantage of different fertilizer formulas for young trees and for full-grown trees in heavy bearing.

Many growers have noticed the tendency of plants fertilized with nitrogen only to die back. Moreover, the quality of the bean appears to be adversely affected. Although the results from the Kainaliu experiment are conclusive for this one location, it should be emphasized that further experimentation is necessary to establish their application to the district as a whole. With this in view, two similar experiments were established, one in North Kona, Holualoa section (1,400 feet altitude), and the other in the Kealakekua section (2,100 feet altitude). The former is in a 5-year-old field, and the latter in an old field of topped coffee. If results of these experiments substantiate the conclusions of the Kainaliu experiment, it will be possible to effect changes in the fertilizer formulas which will result in a much more efficient use of the fertilizer applied.

Analysis of seven samples of coffee cherry taken from widely different locations in Kona showed a fluctuation in the potash content of from 1.67 to 4.03 percent. The pulp from the nitrogen-phosphorus-potassium plats of the Kainaliu experiment contained 3.08 percent, while that from the check plats contained 1.67 percent. Variations in the nitrogen and phosphorus content were apparent but less pronounced. This suggests the possibility of analysis of the coffee pulp as a criterion of the nutritional needs of the coffee plant.

COMPOSTING OF COFFEE PULP

Analysis of the compost from the experimental compost pit at the Kona substation showed a loss of about 50 percent of the total dry matter before decomposition was complete. One ton of fresh coffee pulp, to which 60 pounds of limestone and 25 pounds of superphosphate had been added, produced about 1,000 pounds of final compost with a composition of 2.9 percent nitrogen, 2.7 percent phosphoric acid (P_2O_5), and 3.1 percent potash (K_2O). Observation of the compost pits built by the Kona farmers indicated that anaerobic decomposition proceeds too slowly to be feasible. Apparently, it will be necessary to turn the compost at least twice to effect decomposition in, say, a 7-month period so that the pit can be emptied and the compost applied on the fields during the ensuing summer. To test the effect on speeding up the rate of decomposition, the station compost pit was filled with fresh pulp mixed with thin layers of soil, plus limestone and superphosphate, the purpose of the soil being to furnish a source of organisms capable of more rapid decomposition than those normally present in the coffee pulp.

Farmers recognize the value of coffee pulp as a fertilizer. Fields receiving regular applications show stronger growth with less dieback than those receiving commercial fertilizer only.

ECONOMIC TROPICAL ARBORETUM AND ORCHARDS

The economic tropical arboretum now contains about 600 species. Some of these species, which have already indicated considerable possibilities in Hawaii as cultivated orchard crops, contain many varieties growing in group plantings. Among these groups are:

Annona, avocado, banana, breadfruit, cashew nut, citrus, coffee, date, fig, litchi, longan, Macadamia nut, mamey apple, mango, mulberry, papaya, passion fruit, and sabucaya.

The citrus orchard, which has been developed in connection with many years of experimental work, consists of 238 trees, including 40 different species and varieties. This orchard is a constant source of information in reference to varieties, cultural practices, and insect and plant-disease control, and has supplied propagating material for use in cooperative experiments throughout the Territory. Much of the experimental work in the citrus orchard is discussed in a recent bulletin of the station (*6*).

The avocado, mango, litchi, and date orchards have received attention by the station and have also been made available to the Bureau of Entomology of the United States Department of Agriculture for its fruit-fly investigations.

ANIMAL PRODUCTION

DAIRY

The dairy herd was reduced from 60 to 51 head (including cows, bulls, heifers, and calves) during the year and now consists of 40 Holstein-Friesians and 11 Guernseys. Three young bulls were purchased to replace older animals that were no longer giving satisfactory breeding service.

The general condition of the herd is good. It is free from tuberculosis, and animals positive to the agglutination test for abortion are kept in separate pastures.

The herd not only provides animals for experimental work but is also a laboratory for students in dairy husbandry.

Alfalfa hay was used to supplement the green roughages fed to dairy cows in two 15-week experiments, one with 8 and the other with 6 cows. This resulted in no significant increase in milk yield, but did materially increase the cost of milk production.

Green Sudan grass was compared with green panicum (Para) grass in two experiments each with 6 cows. One experiment lasted 9 and the other 12 weeks. In each case the cows consumed more of the Sudan grass and the milk yields were slightly higher.

The leaves and stumps of pineapple plants (shredded) were fed to three 600-pound Holstein heifers as their sole roughage for 147 days. Consumption ranged from 22 to 45 pounds daily per heifer, depending on the kind and quantity of supplementary concentrates given. No high value was indicated for pineapple plants in this trial, but it was demonstrated that cattle will eat considerable quantities of them and that plants in old or abandoned pineapple fields may be used as emergency feeds in periods of drought.

Cane molasses to the extent of 25 percent of the concentrate mixture was fed for a 7-year period to many cows in the herd (153 cow-years) and the records of 6 years on a nonmolasses ration (146 cow-years) were used as controls. In general, the results show that, when properly supplemented with high-protein feeds, cane molasses in the amounts indicated does not adversely affect production or reproduction or increase the number of abortions and it does result in a material saving in the cost of milk production under conditions prevailing in Hawaii.

No definite benefits were noted from feeding sprouted oats to cows with an irregular breeding behavior, and results to date indicate that under conditions prevailing in Hawaii (green feed available the year round) this method of correcting breeding troubles has little value. To date, 53 cows have been fed sprouted oats.

SWINE

At the close of the fiscal year 1934 the swine herd included 5 Berkshire and 6 Tamworth breeding animals and 17 smaller pigs. At the beginning of the year the herd numbered 44 animals. The reduction in the size of the herd was brought about as a necessary economy measure.

Further work on the feeding value of avocados or papayas (cull or excess fruits in regions distant from market) indicate a fairly high value for avocados and a much lower value for papayas.

Cooked taro scraps (refuse from poi factories) were found to have a fairly high value as a hog feed.

Feeding sprouted oats to sows with an irregular breeding behavior was continued. Not all the sows were benefited but their records were better than those of an equal number of controls, also with breeding troubles, to which sprouted oats was not fed.

POULTRY

The poultry husbandry division maintains a flock of approximately 2,000 chickens, turkeys, and guinea fowls, comprised of breeds commonly found on the commercial farms in Hawaii, for purposes of instruction, demonstration, and research.

ARTIFICIAL ILLUMINATION FOR LAYING STOCK

Pullets that are hatched in November, December, January, and February have a tendency to go into a partial or complete molt before a full year of laying. All-night illumination was tried on early-hatched pullets but proved to be unsatisfactory. For the past 2 years the lights have been turned on at 4 a. m., beginning on September 1 and terminating on March 1. Analysis of the data gathered over the past 2 years shows that the 4 a. m. lighting system has given satisfactory results. Early-hatched pullets did not go into a complete molt during the fall months; likewise the partial molt was reduced approximately 75 percent by the increased length of day. Body weight, after a year of laying, was very satisfactory; practically in all hens a decided gain was noted. Egg production has been greatly increased. The pens on artificial lighting averaged 50 percent more eggs during the months that they were under lights over that produced by the check pens receiving no artificial illumination. A greater number of culls appeared in the check pens, although the mortality was approximately the same for both groups.

A few poultrymen have cooperated with the station in this work, using their commercial flocks from which to obtain data under field conditions. Data from these field trials have not been analyzed to date: however, an increased production and less culls have been reported by all collaborators.

TREE KALE (CHOU MOELLIER) AS A SOURCE OF GREEN FEED FOR POULTRY

Comparison of tree kale with alfalfa as a source of green feed for poultry, which has been in progress for 2 years, indicates that tree

kale is comparable with alfalfa for egg production, fertility, hatchability, and body development.

BATTERIES FOR LAYING AND BREEDING STOCK

The first attempt to house laying hens in hen batteries was made during the year by the Hawaii Station. The hens were divided into three groups according to their breeding, development, and condition. One-half the birds in each group received a fermented yeast mash daily containing 1 percent of "animal-poultry yeast"; furthermore, the three groups were on an entirely different feeding method. Three types of commercial feeding methods were used, namely, the all-mash, mash and scratch, and pellets and scratch. Fermented yeast mash gave best results in all three feeding methods above mentioned. The birds were in better condition at the end of the experiment; they laid approximately 30 eggs more per hen when fed 1 percent of yeast in mash that was fermented for 18 hours. Mortality was approximately the same in all groups. The average yearly production per hen for the entire group was 200.6 eggs. One hen laid 300 eggs and another 297 during the period of the experiment which lasted 365 days.

PLANTATION BACK-YARD POULTRY HOUSES

Four types of houses, each with a floor area of 72 square feet and accommodating 25 hens, were tried with the object of finding a house that was cheap and yet efficient for the back-yard plantation poultry raiser. One year of work on this problem shows that egg production was maintained in a satisfactory manner in all four houses; that the birds in an all-lath house gave the lowest production, whereas the best production was obtained from birds in an 8 by 9 foot house with a solid back and a wire front.

Considerable cannibalism in the form of feather pulling was noted in all four houses. Previous trials at the Hawaii Station have shown that where birds were kept in close confinement, cannibalism was one of the most serious problems with which to contend. Blueprints of the four types of houses have been made and are available to those interested.

SOREHEAD (FOWL POX) CONTROL

In studies of sorehead extending over 7 years, the object has been to determine the method of transmission of the disease to chicks, poults, and squabs, and also to determine the effects of a "live virus" vaccine in developing immunity against the disease. The results of elimination of mosquitoes from the house and run indicate that the mosquito carries the virus to the chick. Chicks 4 to 12 weeks old and poults 3 to 16 weeks old have been successfully vaccinated with a live virus vaccine prepared by the station. In field trials, as a demonstration to show the value of fowl-pox vaccine, approximately 250,000 chicks have been vaccinated successfully. The procedure and the results of this experiment under laboratory and field conditions are described in detail in a circular of the station (*3*).

GIZZARD-WORM CONTROL

The object of this investigation is to determine the cause of the gizzard-worm infestation in Hawaii, particularly in regard to an intermediate host which may be responsible for this new disease. It

was started only within the last quarter of the fiscal year 1934. Considerable losses have been caused directly or indirectly by this worm. One farm reports a loss of approximately 3,000 hens in a period of 1 year. The worm is found on all of the islands; hardly a farm has escaped an attack of this parasite. Not only a high mortality but apparently a decided lowering of egg production has resulted.

There has been very little scientific research on this worm by mainland institutions, primarily because the worm has not infested the large poultry centers. All information received from mainland investigators state that the grasshopper is the intermediate host responsible for the gizzard worm. The station has made a study of infected gizzards, noting especially the physiological characteristic of both male and female worms. Several of the common insects found on most poultry farms in Hawaii have been studied, with no indication as to the intermediate host. Gizzard-worm eggs are being fed to baby chicks to determine whether or not infestation may occur without an intermediate host. Nothing conclusive as to an intermediate host or any other means by which the infestation has appeared in Hawaii has yet been found.

FOOD AND NUTRITION

IODINE CONTENT OF SOME HAWAIIAN MARINE FOOD PRODUCTS

In a continuation of an investigation to determine the iodine content of Hawaiian foods, 18 of the principal fish and 12 of the most widely used seaweeds have been analyzed. The general procedure followed was Remington's modification of McClendon's method, but it was found necessary to alter Remington's procedure in consideration of the particular characteristics of marine foods. To avoid loss of iodine, the bulk of the final ash was increased by adding to each sample before ashing 1 g of calcium carbonate and 2 cc of a saturated solution of sodium carbonate and moistening with hot water. This modified method replaced the Remington procedure, which involved soaking the sample with a 2-percent aqueous solution of sodium carbonate.

The experiments were carried out in duplicate and the results tabulated below show amounts of iodine expressed in parts per billion of the dry sample:

TABLE 1.—*Iodine content (in parts per billion of dry sample) of different marine foods*

Kind of food	Sample 1	Sample 2	Kind of food	Sample 1	Sample 2
Fish:			Fish—Continued		
Ahi	2,100	2,100	Ulua	2,000	1,800
Aholiholi	3,300	3,570	Weke ula	1,910	1,940
Aku	2,600	2,700	Seaweed:		
Amaama	1,500	1,800	Akiaki	411,000	412,000
Au	2,270	2,300	Alaula	127,000	134,000
Awa	2,600	2,750	Eleele	6,408	6,403
Hapuu	2,390	2,320	Huluhuluwaena	157,000	143,000
Kahala	2,500	2,540	Huna	1,980	1,970
Kala	3,590	3,500	Kala	487,000	464,000
Kawakawa	2,700	2,790	Kohu	5,100	5,500
Mahimahi	1,941	1,944	Lipeepee	13,600	13,700
Moelua	2,600	2,640	Lipoa	85,400	85,800
Moi	1,950	2,000	Manauea	143,700	146,300
Oio	1,950	1,900	Opihi	89,100	89,900
Opelu	2,080	2,020	Palahalaha	5,200	5,000
Uhu	5,300	5,000			

STEROL CONTENT AND VITAMIN VALUE OF AVOCADO OIL

The study of avocado oil for its vitamin D value was continued in a new series of feeding experiments with white rats. Animals were fed irradiated and nonirradiated samples of avocado sterol in alcoholic solution. The repetition of the entire vitamin D investigation was undertaken. In previous feeding experiments certain difficulties encountered led to inconsistencies in results. It is anticipated that the present set of animal experiments will lead to more definite conclusions concerning the vitamin D value of avocado oil and avocado sterol.

A CHEMICAL STUDY OF SOME HAWAIIAN PLANTS

POISONOUS PLANTS

Recognizing the fact that there are many poisonous plants of obnoxious character in the Hawaiian Islands, an investigation was started during the year to determine the chemical and physiological nature of the poisons in certain of the plants, and to isolate useful drugs and medicinals. Three plants, pamakani (*Eupatorium glandulosum*), akia, and air plant, were investigated for two common classes of plant poison, alkaloids and cyanogenetic glucosides. The three plants have been shown to be free from detectable quantities of alkaloids.

From pamakani a white crystalline solid melting at 68.5° C. was isolated which analysis showed to have the empirical formula $C_{25}H_{56}O$. Work is in progress to establish the chemical nature and the physiological action of this substance. Similar studies are in progress with akia and air plant and will be extended to other poisonous Hawaiian plants, about 80 of which have been listed.

PASSION FRUIT

The juice of the passion fruit is known to keep unusually long. A chemical and bacteriological study of the various components of the juice was made to determine the cause and, if possible, to isolate a preservative. No alkaloids or common preservatives were found and the conclusion was reached that the unusual keeping qualities of passion-fruit juice are due to high acidity.

VITAMIN B CONTENT OF FRESH DAIKON

Previous studies, which showed the nutritive value of vegetables to be increased by the Japanese method of pickling with salt and rice bran, were continued with the daikon or Japanese white radish (*Raphanus sativus longipinnatus*). The vitamin B of the rice bran was found to be absorbed by the daikon.

VITAMINS A AND D IN THE OPIHI (HAWAIIAN LIMPET)

Biological tests to compare the vitamin A and D content of the opihi with the international standards for these two vitamins showed this shellfish to be an excellent source of vitamin A and a very good source of vitamin D.

ANEMIA STUDIES

Anemia studies in cooperation with C. J. Hamre of the zoology department of the University of Hawaii were continued. The

enlarged spleens found at autopsy in anemic rats were correlated with definite stages of recovery from anemia, judging from the blood studies and histology of the spleens. Studies of young rats from birth to maturity showed similar correlations with the blood picture and the conditions of the spleens.

PROTEIN OF THE PIGEONPEA

Feeding experiments with white rats indicated that cystine had a growth-supplementing value when pigeonpea-seed meal was fed at a level to provide 11 percent of the protein in the diet, whereas, when fed at a level of 8 percent, cystine showed no supplementary value, possibly because at this level some other amino acid is the limiting factor.

VITAMIN CONTENT OF SOME HAWAIIAN FRUITS

Biological tests showed the papaya to be an excellent source of vitamins A and C and a good source of vitamin G, but only a fair source of B. Analyses showed the papaya to be a good source of calcium and sugar. The papaya is therefore a fruit of high nutritive value and should be more widely grown and used by all the peoples of Hawaii.

Although figs are a better source of calcium and iron than are papayas, figs are a fair or poor source of all the vitamins tested.

Pohas, though not an important or widely used fruit, were tested and found to be a good source of vitamins A, B, and C.

Previous experiments have shown that guava juice, prepared as for jelly making, has a high vitamin C content. The juice was prepared by slicing ripe guavas, placing in a saucepan and almost covering with water, bringing to a boil, and boiling gently for 10 to 15 minutes. The juice was stirred frequently to prevent scorching and then drained through a clean flour sack or other cloth. It was then ready for use. Experiments with 14 guinea pigs, 7 of which were fed daily 3 cc of guava juice and 7 a quantity of jelly equivalent to 2 cc of guava juice, showed little or no loss of vitamin C when the juice was made into jelly. This same jelly had no demonstrable quantity of vitamin A.

With the cooperation of a local pediatritian and the nurses at two of the well-baby clinics in Honolulu, it was possible to try out the use of guava juice in place of orange juice as an antiscorbutic for 10 normal babies. Several hundred quarts of guava juice were prepared and bottled, using an ordinary bottle capper. When stored in a dark place at room temperature, the juice kept perfectly for months. The guava juice, given out at the clinic and delivered to the homes, was the only antiscorbutic given for 6 months. The results showed that guava juice, prepared as for jelly making, may serve as a satisfactory antiscorbutic for infants. Many of the babies showed a greater rate of gain than the average for the clinic babies and there was no evidence that the guava juice disagreed with infants of 2 months and older.

JAPANESE FOODS AS SOURCES OF THE VITAMINS

Reports from Japan indicate that tofu (soybean curd) and miso (fermented soybeans and rice) are poor sources of vitamin B, but

preliminary tests in the station laboratory have shown them to be good sources of this vitamin. In addition to their value as sources of calcium, phosphorus, and iron, these two foods should be stressed for the Japanese diet because of their vitamin B content.

Preliminary tests showed miso to have no demonstrable quantity of vitamin A but to have considerable vitamin G.

Lotus root, used by both Japanese and Chinese, was found to have little or no vitamin A and to be only a fair source of vitamins B and G.

Chirimen-iriko, a very small dried fish used by the Japanese (*5, p. 15*), showed little or no vitamin G; rats fed 3 grams daily gained no better than the control. The dried fish, however, proved to be a good source of vitamin A, and a very good source of vitamin D.

HALEAKALA SUBSTATION

Work was continued at the Haleakala substation (elevation 2,162 feet) and on the four associated tracts located at elevation intervals of about 1,000 feet, with the highest at about 6,000 feet.

The extreme conditions of drought in the summer and fall of 1933 enabled the superior grasses and legume varieties under test to stand out in sharp contrast to the native range grasses in the associated pasture areas. The forage crops under test consisted of 32 varieties of grasses, 166 lots of pigeonpeas, 17 varieties of clover, as well as plantings of alfalfa, vetches, and *Meibomia rensoni.*

The root and tuber crops included edible canna, cassava, taro, arrowroot, as well as 25 varieties of potatoes, including the Bliss Triumph, upon which special work is being done to determine its value for new potato shipments to the mainland during January and February, when the markets are otherwise practically bare of new potatoes.

The cereal crops under test included corn, popcorn, barley, oats, rye, and sorghum. There were also planted some 27 varieties of green-manure crops and 28 lots of soybeans.

Twenty-one different varieties of vegetables were planted. The small fruits under test included strawberries, dewberries, Logan blackberries, akala berries, pohas, and 17 varieties of grapes, of which the Isabella appears to be the only one adapted to the local conditions. Fruit trees included avocado, mango, mulberry, prune, nectarine, orange, lime, Bartlett pear, pecan, Persian (English) walnut, almond, Japanese persimmon, apple, cherimoya, loquat, fig, longan, pomegranate, Macadamia nut, guava, mamey apple, star-apple, mountain apple, and mabolo.

Planting material of the more promising forage crops, vegetables, and small fruits was distributed to cooperators who wished to make tests under their local conditions.

The year as a whole was characterized by a very low rainfall. During the 6-month period from May 1 to October 31, 1933, the following precipitation (all in the form of light showers) was recorded: Haleakala substation, 4.93 inches; Olinda, 1.71; Ukelele, 2.07; Mountain Paddock, 0.96; Puu Nianiau, 4.33.

KONA SUBSTATION

The Kona substation, Island of Hawaii, continued to devote its principal energies to the investigation of the various problems affecting the coffee industry. An additional tract of 1.66 acres of adjoining land was obtained during the year and devoted to the testing of different species and varieties of coffee obtained from various parts of the Tropics.

The coffee projects under way had to do with species and variety testing, culture, pruning, and fertilizer-requirement studies, as well as the determination of the best methods, seasons, and stocks for budding and grafting operations. Evidence points to the desirability of utilizing only budded and grafted stock to insure uniformity of yield and a standardized product in connection with coffee and Macadamia nuts, as well as avocado, mangoes, and citrus.

Variety and cultural tests were continued in connection with numerous species and varieties of miscellaneous fruits thought to be of possible promise. These plantings include breadfruit, cashew nuts, cherimoya, figs, Japanese persimmons, litchi fruits, olives, passion fruit, sweetpotato, tomato, and various cover crops which, with the sweetpotatoes and tomatoes, have been intercropped between the rows of young fruit trees.

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